From tool to instrument: an Experiential Analysis of Interacting with Information Visualization

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DECLARATION

I, Sara Faisal Bander Alsaud, confirm that the work presented in the thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Sara Alsaud

ABSTRACT

Information Visualizations (InfoVis) are tools that represent huge amount of abstract data visually on a computer screen. These tools are not reaching the users since constituents of good InfoVis design are still an unknown. In this thesis I argue that good design is one that delivers positive experiences due to the subjectivity of the knowledge gaining processes. Hence, what constitutes a positive experience is the focus of this research. The application domain chosen was the Academic Literature Domain (ALD). ALD InfoVis tools exist; however they do not cater for users' requirements or interface usability, both of which are crucial for a better experience. As a result, an ALD InfoVis tool was created following a User Centred Design (UCD) approach, starting with requirements and ending with usability.

The requirements were first generated based on a qualitative study from which it became clear that researchers equate authors with their publications and position them in terms of the ideas they portray. Based on this, the tool was designed and implemented. The tool's usability was then evaluated through a set of low and high level tasks. Low-level tasks target the visual syntax whereas high-level tasks tap into the generated semantics. The latter allowed for subjective reasoning and interaction, and were therefore used as the basis of the experiential study. The experiential study captured users' experiences by relying on a Grounded Theory (GT) analysis. This study resulted in the generation of a base theory of InfoVis interaction that properly fitted within the context of the instrumental genesis theoretical framework which argues for the design of instruments not tools, where instruments are mental appropriations of tools. The theoretical approach applied by this research has value across InfoVis even if not tailored for evaluation.

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FOREWORD

Much of this work has been presented in published papers. These papers are listed below. The full details of the paper may be found in the references.

Chapter 2, 3

(Faisal, Cairns, & Craft, 2005)

(Faisal, Cairns, & Blandford, 2006a)

Literature review and a discussion of users' interaction with InfoVis tools and associated activities

Chapter 5

(Faisal, Cairns, & Blandford, 2006b)

A detailed account of the requirements gathering

Chapter 6

(Faisal, Cairns, & Blandford, 2007a)

Translating the requirement into a design of a working InfoVis prototype

Chapter 7

(Faisal, Cairns, & Blandford, 2007b)

Evaluating the usability of the interface

Chapter 8

(Faisal, Craft, Cairns, & Blandford, 2008)

A primary account of part of the experiential analysis with emphasis on the importance of theoretically looking at InfoVis as an experience

All the above works were written in the course of my Doctoral studies with my supervisors as co-authors in normal academic practice. Brock Craft assisted in reviewing Faisal et al (2005) hence

acts as third author, in addition he wrote a literature review on qualitative research in Faisal et al (2008), hence acting as second author on that particular paper.

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1. Introduction

How can we design good Information Visualization (InfoVis) tools? This question reflects the aim of this research. Information visualizations are tools that represent large amounts of data visually on a screen in order for users to gain information and insight of the represented domain. We are living in the information age where information is exponentially growing all around us. Yet, InfoVis tools are not reaching their optimum, as research is mainly technology oriented. InfoVis research, only recently, has started to consider the users and their needs as part of the development and evaluation cycles of these tools. As a result, there has yet to be an agreed upon methodology and/or framework with which to design and evaluate these tools. Users, when interacting with InfoVis tools engage in highly cognitive and goal oriented activities with which knowledge and insight of the represented domain are gained. The means with which the users make sense of these representations is subjective as it is dependent on their backgrounds and past experiences, making users' interaction with these tools an *experience*. As a result, this research takes an experiential stance on users' interaction with these tools.

This thesis taps into the areas of both InfoVis and HCI research. It contributes to InfoVis research by taking a first step in generating a theoretical understanding of users' interaction with InfoVis tools. This was achieved by applying a User Centred Design (UCD) approach, which is emergent from HCI, in order to design and evaluate an InfoVis prototype of the Academic Literature Domain (ALD). The aim of this chapter is to introduce the reader to the main research problem, objectives and contributions through a discussion of the motivations that inspired the ideas addressed by this research.

1.1 Information Visualization: A Few Examples

This research focuses on the domain of InfoVis. InfoVis are tools that generate visual externalizations of abstract domains, which are generally interactive. Tweedie (1997) refers to InfoVis tools as *interactive externalization*. Due to the abstractness of the domains, there are no corresponding real-world representations. Hence, designers rely on representations such as trees, graphs, and scatter plots, to visually represent the data. An example of these tools is seen in Figure

1.1. This is a screen shot of a tool that was developed by Chen (1999). The visual representation is used to reflect academic literature data, where the nodes represent the authors and the links represents the author co-citation relationship, i.e. authors that are constantly being cited in the same context.

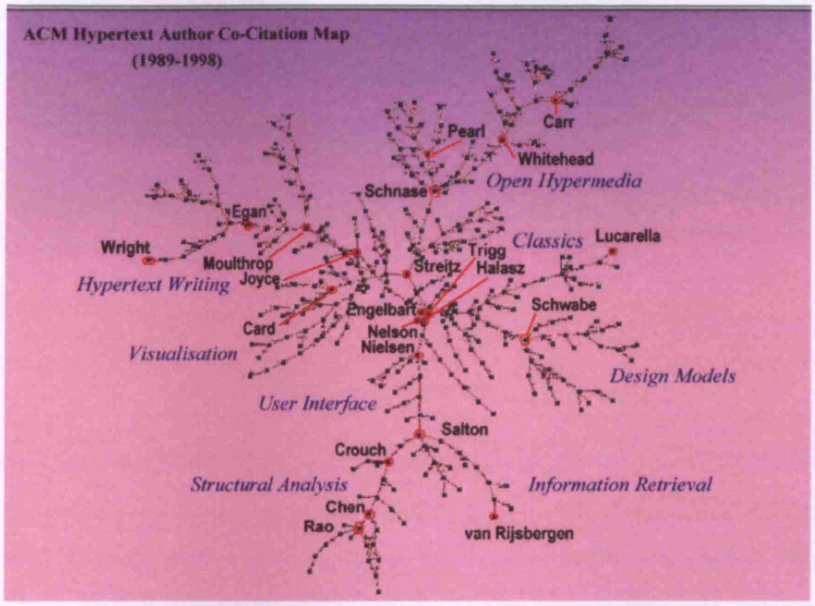


Figure 1.1 Hypertext author co-citation map (Chen, 1999)

The aim of this visualization is to identify the emerging research trends within the field of hypertext research. Merely by looking, the visual representation is hard to understand unless the user is trained to do so. This is due to the fact that this type of visualization is designed to target expert users, known as domain analysts, who analyze the evolution of scientific domains in order to identify information, such as emerging research trends.

Another example is depicted in Figure 1.2. This visualization is called the HomeFinder (Ahlberg, Williamson, & Shneiderman, 1992). The aim of this tool is to assist users who are looking to buy a home in the Washington D.C. area. This visualization is very interactive; hence users need to communicate their goals to the system by specifying the criteria of the homes that they are looking for, such as: number of bedrooms, cost, and area of interest. The system filters the information accordingly. The houses are depicted by the yellow dots on the screens, and they are only visible if they fit the specified criteria. This visualization targets a problem that is common and that people of varying backgrounds and experiences face at some point in their lives.

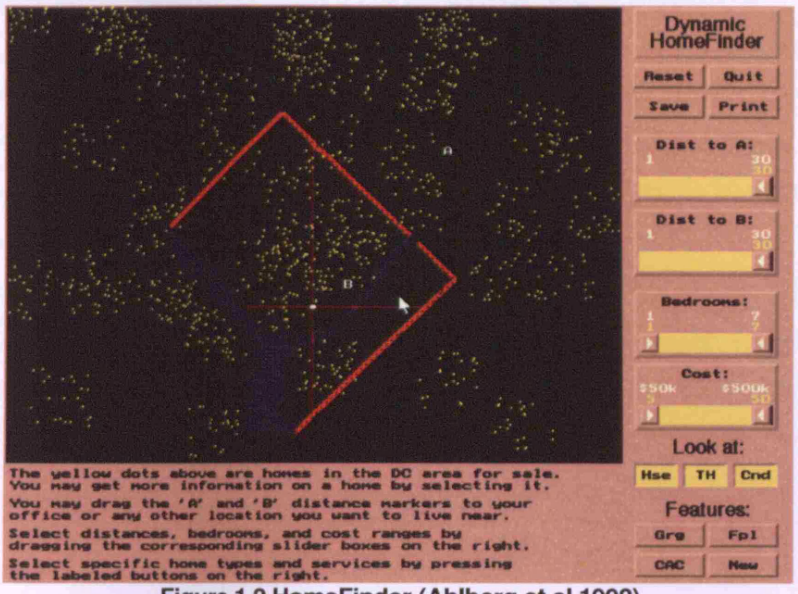


Figure 1.2 HomeFinder (Ahlberg et al 1992)

Unlike the citation tool, explained in the previous example (Figure 1.1), HomeFinder targets general users and not property experts. The means with which users reason and navigate through the representation is subjective as it is dependent on users' backgrounds and current needs. Interactivity of the tool is essential in situations such as this where users have varying goals. Merely by comparing the interface design of the citation tool (Figure 1.1) and the HomeFinder (Figure 1.2) it can be seen that the HomeFinder interface incorporates on-screen widgets which is an indicator of the highly interactive nature of this interface. It is through users' interaction with the interface and associated widgets that they are able to manipulate the externalization in order to achieve their goals. The innovation when it comes to the HomeFinder is related to the interface and associated widgets; this will be addressed in Chapter 3. Whereas the innovation of the citation tool (Figure 1.1) is related to the external visual representation, externalization of the data.

InfoVis tools that target the general user, such as the HomeFinder application, are the focus of this research. People are faced with huge amounts of information that they need to interact with and manage as part of their daily activities. InfoVis tools can help, as they exploit people's natural perceptual abilities in order to generate insight and knowledge of the represented domain. However, these tools are not reaching the users. This is mainly because users' needs and desires within the context of InfoVis tools are not well understood. Hence, it is not known what distinguishes a good InfoVis tool from a bad one: is it related to the usability of the tool, to the amount of insight and knowledge communicated to the user, or is there more?

1.2 Research Motivation: Externalization Vs Interface

This research's motivation stems from looking at users' interaction with InfoVis. This interaction, as defined by InfoVis literature relies immensely on users' cognitive processing. It is defined as the process of creating mental images of the visually represented domain (Spence 2001). Users interpret the visual data patterns into meaningful information which in turn satisfies some initial domain related goal, making the visual aspects of great importance when it comes to InfoVis. Lots of research has been conducted in InfoVis which concentrates on coming up with various and creative visual representations, as seen from the above examples. However, users' interaction with InfoVis tools is not solely dependant on such a visual interaction, it is also dependent on their interaction with the interface in general, as can be seen by the following scenario, represented by Figure (1.3).

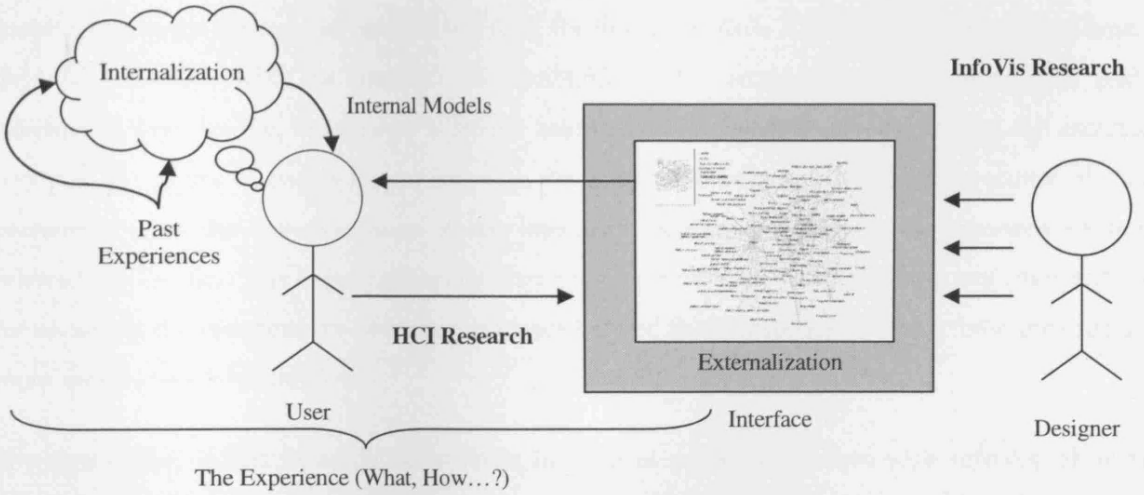


Figure 1.3 Motivation: Users interaction with InfoVis is based on interacting with the externalization which is embedded within an interface

The user, when interacting with the InfoVis tool, interacts with highly complex visual representations, known as externalizations, of the represented domain which have been created by the designer. In order for the user to satisfy her intended goal, she engages in cognitive activities that generate internal models of the represented domain (Ware, 2004). However, the generation of these models is not an isolated process, it is part of an internalization process which is influenced by the user's past experiences and knowledge of the world (Vygotsky, 1978), which will evidently have an influence on the building of these models and consequently, on the knowledge that is gained. For example, the user is looking to buy a home and hence uses the HomeFinder application, described above. This user has two children and has previously lived in area A, and hence she is

aware that it is a safe area. As a result, she looks for a home in area A. After studying the externalization of the data, she learns that there are merely a few houses in area A which are on the borders of the area that satisfy her living conditions. She also discovers that the prices of these homes are excessive. From this small example it can be seen that the user had previous knowledge of the domain and through the interaction with the visual representation additional knowledge has been gained which changed the internal model that she had of the domain, whereby she now considers area A as being overly priced and not suitable for her needs.

Looking closely at users' interactive experience with the InfoVis tool it can be seen that this interaction is not solely dependent on the generation of domain related mental models, but is also dependent on the users' interaction with the interface. It is through this sort of interaction that the user will be able to communicate her needs to the tool and consequently satisfy her intended goals. Following on from the previous example, after determining that area A was overly priced she then decides to change the area of interest and look for homes in Area B. As a result, she would have to physically interact with the interface to communicate her request. It is this interaction that is referred to here as the interaction with the interface. Externalizations are part of the interface; however the nature of user's interaction with the externalization is different to the nature of user's interaction with the functionalities of the interface, as demonstrated by the previous example. Where with the first it is dependent on domain related knowledge and reasoning activities and with the second it is dependent on executing interface related functionalities. Both of these are crucial to users' interaction with InfoVis.

The motivation of this research stems from looking at users' interaction with InfoVis. However, interaction when it comes to the field of InfoVis has not been explicitly studied as the focus has mainly been on the generation of externalization. Hence, it can be said that the study of interaction in InfoVis has suffered compared to the visual aspects even though it plays a major role in users' interactive visualization experience. This is due to the fact that it is through users' interaction with the visual externalizations of the data that knowledge and insight of the domain is gained (Chapter 2). On the other hand, the study of interaction has thrived when it comes to HCI research, specifically when it comes to studying users' interaction with the interface, as will be discussed in Chapter 3, where interaction models of users' interaction with the interface will be discussed. These will be discussed from the context of Direct Manipulation (DM) as it is the interaction model that is applied when it comes to InfoVis interfaces, where users directly interact with onscreen iconic representations. As a result, specific functionalities are executed. This

research differs from the InfoVis and the HCI literature when it comes to studying interaction within the context of InfoVis whereby it looks at user interaction with the externalization embedded within an interface. In other words, it looks at users' domain related subjective reasoning activities embedded within the context of an interface.

In this research users' interaction with InfoVis is seen to be more than the effective execution of tasks, it is seen as an umbrella under which a fulfilling user experience is generated, such an experience goes beyond usability (Norman, 2004). This research will adopt an interaction-centred approach (Frolizzi and Battarbee, 2004) whereby users' interaction with InfoVis will be looked at from a holistic perspective (McCarthy and Wright, 2004). By doing this questions such as: what constitutes such an InfoVis experience, and how can we design for a better experience? will be answered.

1.3 InfoVis as an Experience

As seen from the previous discussion, there is more to users' interaction with InfoVis tools than merely the interface. It is an experience that relies on users' backgrounds and knowledge which results on the gaining of insight and knowledge. From the dictionary[1], two definitions of experience were relevant to the matter at hand.

Experience: An active participation in events or activities, leading to the accumulation of knowledge or skill

Experience: The apprehension of an object,... through senses or mind

Experience is viewed as an activity in which participants are active. This participation leads to gaining a certain comprehension and knowledge. The way this activity is formed and what is gained from it is closely related to the way in which Spence (2001) describes visualization. He describes it as a *cognitive activity* with which users are *engaged* with the potential of *gaining* insight and an understanding of the represented data. When interacting with visualization tools, users may have specific goals or hypotheses that they would like to examine, or they might interact with the tool to simply gain insight of the domain. As the users interact with the tool, "ah HA!" moments arise, as Spence (2007) describes. How and when these moments are reached differs from user to user. It is these "ah HA!" moments that makes them an experience, as it is something that is unpredictable, that cannot be pre-calculated.

[1]The American Heritage

The study of user experience has recently been a popular topic in HCI research. However, the concept of 'user experience' is still quite immature. Over the past years researchers have been attempting to reach a cohesive theory or framework which has yet to be achieved. The main problem lay on the fact that researchers of such a concept come from differing backgrounds such as: cognitive science, ethnography, social and behavioural sciences, each relying on their own backgrounds and applying their own methods of research. Hence, miscommunications may arise which might also result in redundancies of effort, where similar ideas might be reached and yet not be apparent. When it comes to user experience research in HCI there are two main trends, cognitive science approaches and a more holistic phenomenological approach (Swallow, Blythe, & Wright, 2005). In cognitive science it is related to the study of the user, whereas in phenomenology it is represented as the relationship between the individual and the object within a specific context. The work produced by this research falls under the phenomenology approach as it aims at generating a holistic view of what constitutes users' InfoVis experiences. To effectively address that, an InfoVis prototype of the Academic Literature Domain (ALD) was developed and evaluated. Each phase of the development and evaluation of the prototype has contributed to this research's overall contributions.

1.4 Research Overview

This research revolves around a UCD process which starts with the requirements gathering of a prototype and ends with its evaluation. The implemented prototype is an InfoVis tool of ALD.

1.4.1 Academic literature visualization

The ALD represents the literature data within an academic context. It includes information such as: authors, papers, citations, journals, etc. Users of such domains are mostly researchers in an academic field, since it is important for them to keep track of the literature being published. In addition, they need to have a complete and global understanding of the community, how it evolves, and how it relates to other research communities. The reason this domain was chosen is due to its wide range of users who have real needs and goals. From reviewing InfoVis literature (Chapter 4), ALD InfoVis tools exist and are categorized into two main categories: Knowledge Domain Visualizations (KDViz) and Information Retrieval (IR) Visualizations. Neither category satisfies the needs of this research for reasons that can be summarized in the lack of one or more of the following: interaction, conceptualization of users' understanding and/or usability studies. I believe

that each of these features is essential for the fulfilment of the user InfoVis experience, which is central for this research. Hence, an ALD InfoVis tool was designed and evaluated. The design of the tool was based on a requirements gathering study.

1.4.2 Requirements and design

Requirements of the tool were generated (Chapter 5) which differed from what existing tools had to offer. The requirements generation process was based on a qualitative study that was analyzed using Grounded Theory (GT) (Strauss & Corbin, 1998). I believe that this is essential due to the fact that InfoVis tools are externalizations of the domain and in order to design them we need to understand users' internalizations, internal models, of the domain. A high level descriptive theory of researchers' academic literature experiences was generated, specifically within the context of HCI and Psychology as they represented the participants' backgrounds. From this descriptive theory, the tools' requirements and design rationale were generated. The design process (Chapter 6) took careful consideration of both aspects of users InfoVis experiences, the external representation, and the interface (Figure 1.3). This tool differed from other existing literature InfoVis tools especially when it came to the adopted design rationale and portrayed information. This tool represents the focus of the evaluation studies conducted by this research.

1.4.3 Evaluating InfoVis tools

Evaluating InfoVis tools is a challenge that is still being addressed by InfoVis researchers. Chen (2005) indicated that usability is one of the main unsolved challenges in InfoVis research as there is not an agreed upon evaluation methodology. Two studies were conducted to evaluate the ALD InfoVis tool. The first aimed at evaluating the tool's interface and the associated visual representation, whereas the second aimed at evaluating the users' overall experiences.

Usability study

The first study (Chapter 7) took the form of a task-based usability study. The aim was to evaluate the usability of the interface, as the interface is crucial to users' InfoVis experiences. The study captured the tool's effectiveness, efficiency and users' satisfaction. The effectiveness was measured by the correctness of users' answers to the given tasks (i.e. insight that was gained), efficiency was measured by the time it took users to accomplish these tasks and user satisfaction was measured using the Questionnaire of User Interface Satisfaction (QUIS) (Chin, Diehl & Norman 1988). This study assisted in effectively evaluating the interface in addition to probing the inadequacies of

traditional usability studies when it came to evaluating InfoVis tools, which led to further understanding of the nature of InfoVis tools compared to other interfaces.

Experiential study

The second study (Chapter 8) relied on a qualitative evaluation methodology which is uncommon when it comes to evaluating InfoVis tools, especially within a lab setting. The reason such a method was relied upon was due to the need to generate a holistic understanding of users' experiences interacting with the InfoVis tool. There is more to InfoVis than merely the interface. The interface is the façade that the users manipulate in order to generate knowledge and insight of the represented domain. The experiential study conducted (Chapter 8) assisted in generating a high-level theoretical model of users' experiences of interaction with the ALD InfoVis tool. This can be seen as a positive starting point in unravelling users' InfoVis experiences when it comes to interacting with subjective domains, such as the ALD. GT was relied on in order to generate the high-level theory.

Due to the atypical method taken by this study it was felt necessary to ground this work in an established theoretical background. The instrumental genesis approach (Rabardel & Bourmaud, 2003) was ideal. Instrumentalism is a theoretical framework that provides a detailed account of peoples' interaction with artefacts. It argues that the effectiveness of the artefact should be depicted in terms of the ability of people to transform the artefact into an instrument through appropriation, where an instrument is a psychological representation of the artefact. The generated InfoVis experiential model is theoretically grounded which indicates the possibility of its generalisability to the InfoVis domain as a means to understanding users' interaction with InfoVis tools. The generated model can be viewed as the unpacking of interaction within the context of InfoVis. As a result of this understanding, in addition to the experiences gained as part of the design and evaluation of the ALD InfoVis tool, design implications were identified (Chapter 9). Some of these can be generalisable and others are specific to the ALD InfoVis tool.

1.5 Research Aim and Objectives

Plaisant (2005) calls for the need of designing InfoVis tools that target the general public and not merely the expert. Designing for such users is a challenge due to their diversity and varying goals. This research's aim is to design good InfoVis tools that target such users. However, before this can be achieved there is much that needs to be done. As a first step the relationship between the goal space and the device space need to be understood in order to determine how they can effectively be yoked, as discussed in Section 1.2. In order to do so, this research unpacks the meaning of

interaction within the context of InfoVis. This is done by generating a holistic understanding of users' experiences interacting with InfoVis tools. Since this understanding is based on users' interaction with an InfoVis tool, the ALD was chosen as the domain of interest, as discussed. No existing ALD InfoVis tool that satisfied the needs of this research was identified; hence a tool had to be designed and implemented. The design and evaluation of InfoVis tools is a challenge due to the fact that an agreed upon design and evaluation framework/methodology is non-existent. Hence, a UCD approach was adopted. The implemented tool took part in two evaluation studies: a study that looked at the usability of the interface, and an experiential study from which a theoretical understanding of users' interaction with the ALD InfoVis tool was generated. Point solutions are not the aim of this research; it is generalisability that is the goal. Hence, theoretical grounding is an essential objective.

1.6 Research Contributions

This research's contributions will be explained in detail in Chapter 10. The following is merely a preview of the areas where the contributions have been made. The research contributions are presented in terms of their specificity. Global contributions are related to the InfoVis field and specific contributions are related to the application domain, which is the ALD.

1.6.1 InfoVis contributions

1. UCD process for the design of InfoVis tools
2. Probing the inadequacies of usability when evaluating InfoVis tools
3. An experiential insight on the evaluation of InfoVis tools
4. Unpacking the meaning of interaction within the context of InfoVis
5. The value of theory generation due to its generalisability

1.6.2 Domain related contributions

1. Identify a descriptive theory of how researchers (across the field of psychology and HCI) make sense of their literature domain.
2. From this descriptive theory the requirements of ALD InfoVis tools were generated where concepts such as subjectivity and personalization were identified.
3. The design of an ALD InfoVis tool which differed from other existing tools (experiential design implications).

1.7 Scope of the thesis

As part of this research a qualitative study was conducted across the domains of HCI and psychology in order to generate the InfoVis tools' requirements. From this study a descriptive theory was identified of how researchers across these domains made sense of their literature. No attempt has been made to generalize this academic literature sensemaking theory across other domains. These requirements are used as the basis of developing an ALD InfoVis tool. The ALD InfoVis tool is the tool that was used in the evaluation studies. The findings of this research target InfoVis tools that represent subjective domains, such as the literature domain where users' goals are not clearly defined. It is important to note that this research does not address expert workers or analysts who are trained in understanding and deciphering complex visual representations. This research addresses the needs of non-experts and determines ways in which they can take advantage of InfoVis tools.

1.8 Structure of the Thesis

This thesis starts with a literature review which is laid out across three chapters (Chapter 2, 3, and 4). The arguments in these chapters aim at taking the reader from an overview of the areas of research to the specificity of the problem. The argument starts by giving the reader an overview of the InfoVis literature concentrating mainly on users' interaction with the visual representation and the resulting internal models (Chapter 3). Following is a discussion of users' interaction with the interface discussed within the context of HCI (Chapter 3). An overview of the application domain, academic literature InfoVis tools follows (Chapter 4). The main literature review is covered in these chapters but some of the following chapters have an integrated literature review depending on the focus of the particular chapter.

This research is based on a UCD process, where a prototype of the ALD InfoVis was designed (Chapter 6) implemented and evaluated (Chapter 7, 8) based on users' requirements, which was generated as part of a qualitative study (Chapter 5). The layout of the chapters is seen in Figure 1.4. Following on from the evaluation studies, a discussion on the implications that the experiential understanding has over the design of InfoVis tools is presented in Chapter 9. Finally, the conclusion and future work follow in Chapter 10.

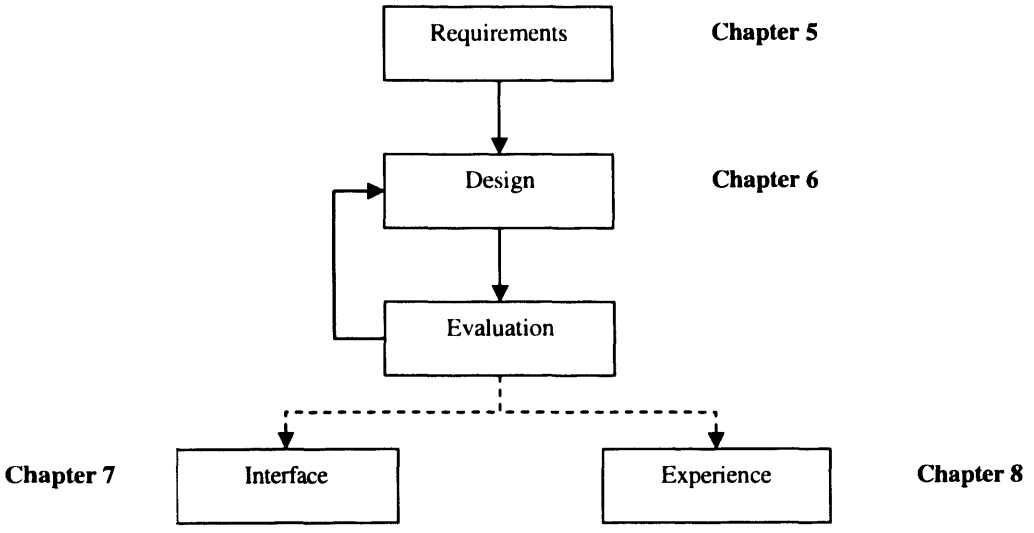


Figure 1.4 Research plan: A User Centred Design (UCD) process

2. Users and the External Representation

2.1 Introduction

The aim of this research is to design InfoVis tools that target the user. Users interact with InfoVis tools in order to satisfy specific goals. As discussed in Chapter 1, users' accomplish these goals by interacting with the visual externalization of the data. As users interact with the visual externalization, information such as, patterns, commonalities, or even dissimilarities are identified which leads to the gaining of domain related knowledge. This chapter shows that the production of these visual externalizations has been, until quite recently, the focus of InfoVis literature where users' needs have not been taken into account. Hence, the focus has been on the developers' roles and not the users'. Externalizations are predetermined by the designer. Hence, they are a reflection of the designers' personal conceptualizations of the represented domain. However, users' interaction with the externalization is based of their personal conceptualizations and past experiences.

Users when interacting with the visual externalizations engage in cognitive activities from which internal models of the domain are generated. Internal models are subjective as they depend on users' past experiences, needs and backgrounds; making users' interaction with InfoVis tools an experience. This chapter discusses these issues by first reviewing seminal InfoVis development models highlighting the lack of user consideration in such a process. Following that, it discusses users' roles when it comes to interacting with InfoVis externalization, pointing to its subjectivity. This leads to a discussion as to the reasons why this research considers users' interaction with InfoVis tools an experience.

2.2 InfoVis and the Abstractness of the Domain

The visualization field is divided into two conceptually similar subfields that are applied in two distinct domains, Scientific Visualization and Information Visualization (InfoVis). The difference mainly relies on the nature of the data and the concepts that are being visualized, in addition to the targeted audiences.

	Scientific Visualizations	Information Visualizations
Data	Real World Concepts	Abstract Concepts
Goal	Clarification of a phenomenon	Searching for a Phenomenon
Activities	Confirmation or rejection of a hypothesis	Exploratory activities
Users	Expert scientists	Wide range of users

Table 2.1 Scientific Visualization vs. information Visualization

Scientific visualizations

Scientific visualizations (Table 2.1) visually represent concepts such as: molecules, parts of the human body, the earth's properties, or natural phenomena (Card, Mackinlay, & Shneiderman, 1999) mostly in 3D. Scientific visualizations are also known as confirmatory analysis visualizations (Keim, 2001) due to their goal, which becomes either the confirmation or rejection of a certain hypothesis. Most users of these systems are trained scientists.

Information Visualization (InfoVis)

InfoVis, which are sometimes referred to as abstract InfoVis (Shneiderman, 1996), are visualization tools used to visually represent abstract concepts (Table 2.1) since the associated data has no clear physical representation (Gershon, Card, & Eick, 1998). For example: currency fluctuations, prices, flight schedules, literature data etc. The represented data in this case is not the real thing as in scientific visualizations (Spence, 2001), but visual patterns such as clusters which are intended to reveal concepts extracted from the data. The InfoVis application domain is wide as it need not merely represent the scientific domain. Keim (2001) classifies these visualizations as exploratory analysis visualizations, where the goal is to assist the user in identifying a hypothesis, unlike with scientific visualization where the goal is to clarify already created hypotheses. Hence, users' of these visualizations may range from trained professionals, such as domain analysts who use author co-citations maps (Chapter 1) to identify emerging research trends of an academic field, to non-specialist users, such as people trying to buy a home using the HomeFinder (Ahlberg et al 1992), as explained in Chapter 1. This research looks at academics and the ways in which they familiarize themselves with their literature domain. These are professional users; however, their goals are not as concise as the domain analysts' due to the social and conceptual aspects involved in the reasoning process, as will be discussed in Chapter 5.

2.3 InfoVis Developmental Models

The process of creating the visual representations is highly technical. Ware (2004) summarizes the InfoVis development process into four basic steps which starts with the data gathering and ends with the users' perception of the visualization; these steps are:

- Gathering and storage of data.
- Pre-processing and data transformation
- Graphics algorithms and computer hardware
- Human perception – the user

These steps are elaborated as follows. After the data is collected, it is stored in databases. Transformations occur on the data, whereby attributes and relationships are identified. Following that, computer algorithms are used to manipulate the data and graphically generate the visual representations. Last but not least, the user interacts with the visualization and information of the domain is perceived. InfoVis models exist; one of the most prominent is the one presented by Card et al (1999), known as the InfoVis reference model. The general steps that take part in the development cycle of InfoVis tools are the same as the ones previously presented. This model is depicted in Figure 2.1.

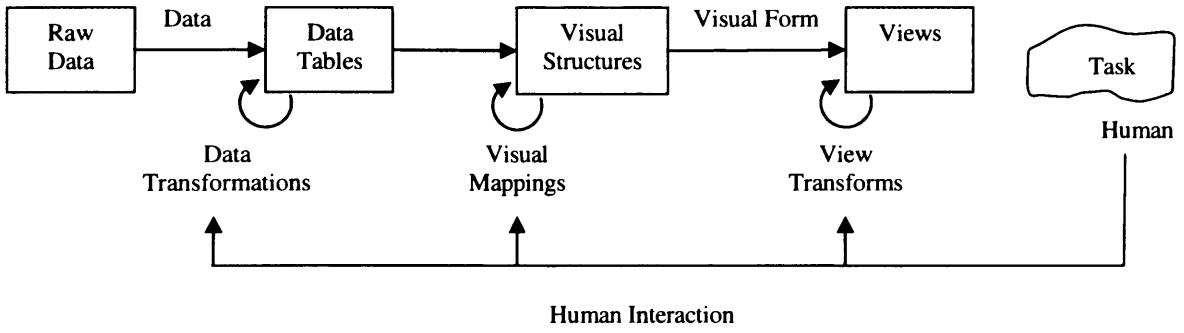


Figure 2.1 Reference model for visualization (Card et al, 1999)

As seen in the above figure, the process starts with the raw data which are stored in data tables. Due to the abstractness of the domains certain pre-processing needs to be conducted in order to generate information such as: identify relationships, calculate term frequencies, etc. This is done through the transformation step. Following that, visual mappings are mapped onto the data in order to give the data spatial and graphical properties. Finally, view transformations are used to create views of the visual data structures. It is these views that users of the visualization will interact with. As the users interact with these views, they might request the presentation of different views as they are working towards achieving their goals. In this reference model it is hard to distinguish between the role of

the developer in the development process and the role of the user in the interaction process. By looking at Figure 2.1 both roles are merged into one which is the 'human'. The user has a specific task in mind and hence executes the task by interacting with the views. However, users' needs are not considered as part of this model as these needs are executed through users' interaction with the interface.

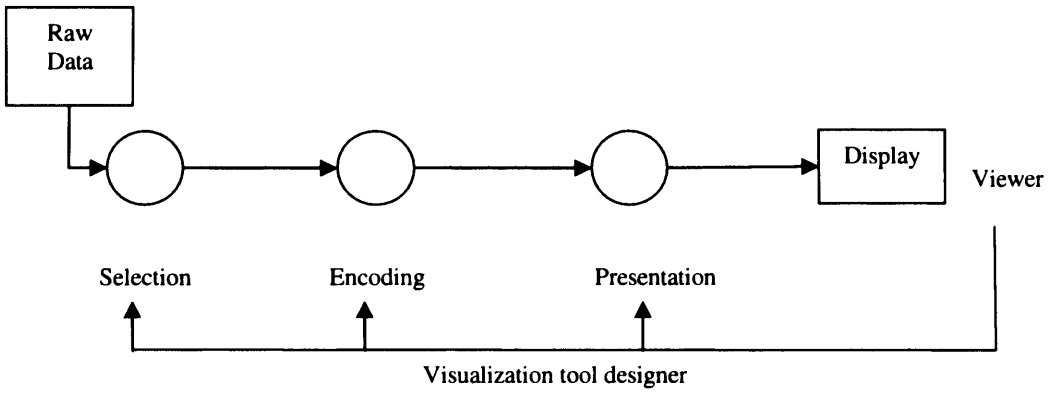


Figure 2.2.The Creation and use of a computer-based visualization tool (Spence, 2001)

Spence (2001) proposes a generalized model which explains the general steps involved in the development of an InfoVis tool. In Figure 2.2 it can clearly be seen that the steps involved comply with the model presented in Figure 2.1. However, in this model Spence explicitly refers to both the designer and the viewer which is the user. Yet it is still not clear how the goals and activities of each differ. Users interact with the visualization, and designers design the users' interactive tasks in a way that satisfies the users' interests. It is important to distinguish the roles of the designer and the user as it is the user that this research is interested in.

The developer

From the developer's perspective the InfoVis creation process can be summarized as follows: after the raw data has been collected the developer selects the relevant parts of the data. Where and how it is stored will depend mainly on the application's needs. Necessary transformations are performed on the data. Following that, the developer decides on the visual encoding mechanisms that best suit the data. From there, using computer graphics algorithms, visual representations of the data are created and graphical views of the data are generated. The developer's main role is deciding on how best to represent the externalization with which the user will interact and then implementing the algorithms that will produce these externalizations. The development process is very technical, yet creative.

The user

From the user's perspective, once the InfoVis system has been created the user interacts with, and manipulates, the visualization at hand. The user is usually not aware of the technical transformations that occur on the data. As the user interacts with the system's interface, models of the represented domain are built in the user's mind (Spence, 2001). As a result, knowledge of the domain is gained. By interpreting the graphical representations further, the user engages in sensemaking activities (Russell, Stefik, Pirolli, & Card, 1993) by which additional knowledge and insight are gained.

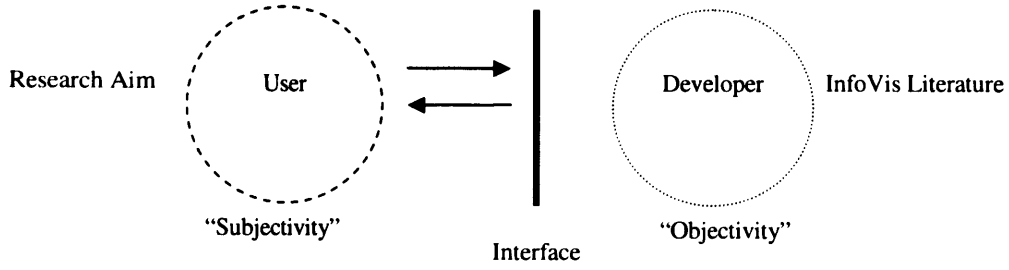


Figure 2.3 The focus of this research is on the user as opposed to InfoVis literature where the focus is on the developer

Most of the research performed in the field of InfoVis concentrates on the developer's role, as the development is the goal. This research is interested in the user and hence concentrates on the user side of the visualization process (Figure 2.3).

2.4 InfoVis and Users' Goals

Based on InfoVis literature users' goals are mainly accomplished as a result of their interaction with the externalization. It is through such an interaction that they are able to accomplish their goals and hence gain insight and knowledge of the represented domain. Externalizations, as defined by Spence (2001), represent all that the user can see of the visualized data. Users' interaction with InfoVis tools is highly cognitive. Ware (2004) indicates that visualization has moved out of the mind and onto the computer screen. This is true when looking at visualizations from the designers' perspective. Designers produce technologies, as explained earlier. However, when it comes to users, these activities are still very much in the mind (MacEachren, 1995). As users interact with the externalizations, models of the domain are created in users' minds. These models are subjective as they are dependent on users' past experiences. Spence (2001) explains the cognitive nature of users' interaction with InfoVis tools by relying on the navigation framework (Spence, 1999).

2.4.1 Navigation framework

The navigation framework (Figure 2.4) is used to guide the discussion of users' activities when it comes to interacting with InfoVis tools. It is important to note that this is the only framework that we are aware of that has been used to discuss users' activities within the context of InfoVis.

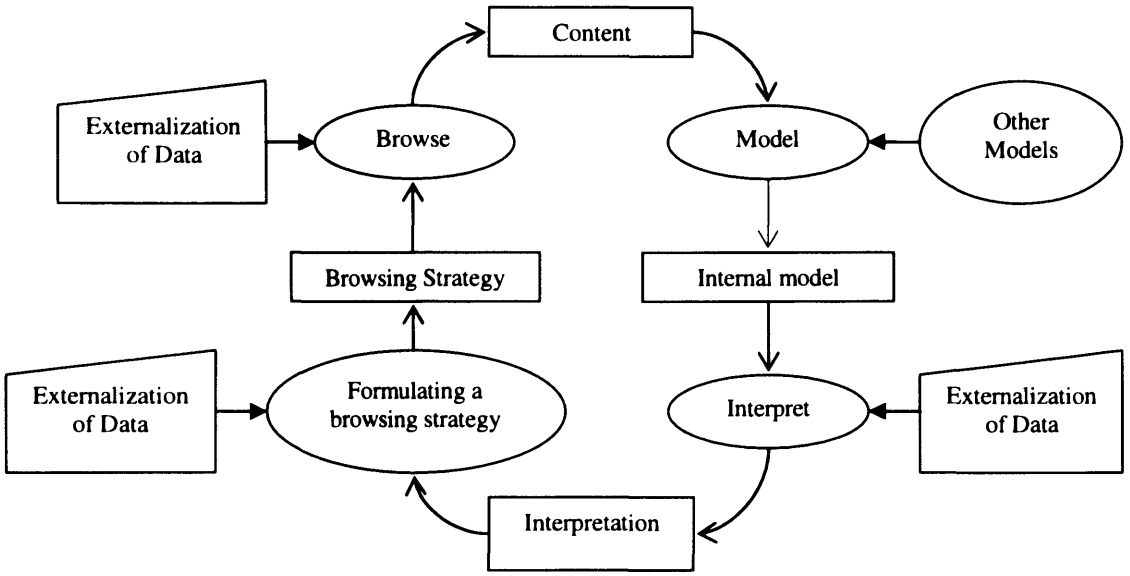


Figure 2.4 The navigation framework (Spence, 2001)

Users, when interacting with InfoVis tools, engage in four cognitive activities: browse, model, interpret, formulate. All, but one, of these activities are dependent on the data externalization, except for the modelling activity, which is reliant on models that users create as part of their past experiences (Figure 2.4). In order to explain this model, the following is an example of a user interacting with the HomeFinder which was described in the previous chapter (Figure 1.2). The example is based on the following scenario: "Sam is in the process of looking for a home to accommodate him, his wife and his two children. He has a rough idea of the area he wants to buy in and has a set budget."

Browsing – registration of content

As Sam starts to interact with the HomeFinder tool, he thinks to himself: "let me see what is out there?" as he does not have a specific target yet. However, Sam is browsing the externalization with specific *weights* in mind. The weights that guide the browsing determine the information that is worth looking at. Sam has well defined weights when it comes to the budget and the number of bedroom, but less defined weights when it comes to the area. Sam starts to register the available content.

Model – the formation of an internal model

The content that has been registered by Sam as being important starts to integrate as part of his internal model. This is not the first time that Sam has been home hunting; as a result, he is relying on the knowledge generated as part of his previous experiences; for example, he knows that homes which are located at the city centre are always over priced.

Interpret – decisions on how to proceed

He interprets the models created of the situation, and as a result identifies 150 homes that look interesting. It is impossible to browse through them all. Hence, he decides to narrow the area.

Strategy formation – forming a new strategy based on the current situation

As a result, he starts the navigation process all over again; however, this time the browsing weight which is related to the area is strengthened. The process goes on, until the goal is attained.

The navigation framework points to the fact that most of the activities that Sam has engaged in are very much in his mind. Sam first looked at the visual representation, perceived it, and started browsing the content in order to determine the important information. As part of this process an internal model of the domain, homes, was being built. This model relied on his needs and goals in addition to internal models that he has previously generated as part of his earlier experiences. As a result of the interpretation of these models, his browsing strategy was refined, and the process went on.

Internal models are a concept that has been discussed thoroughly in HCI. However, in HCI internal models mostly rely on the models that the users build and rely on as part of their interaction with the interface, whereas in InfoVis internal models refer to the models that users build of the externalization of a domain.

2.4.2 HCI: Interface related models

Mental models are very widely discussed in HCI. The term was first originated by Craik (1943); following that, it reappeared in cognitive science with the publications of two books in 1983 titled "Mental Models". One was by Johnson-Laird and proposed mental models as a means to describing the process with which people solve deductive reasoning problems. The other was by Gentner and Stevens (1983) and proposed that mental models are used to provide people with information on

how systems work. Carroll and Olson (1987) define mental models as being *"a representation (in the head) of a physical system or software being run in a computer, with some plausible cascade of causal associations connecting input to the output"*.

From an HCI perspective mental models reflect users' understanding of how a system works. They are related to the interface and use of the system (Preece, Rogers, & Sharp, 2002). Norman (1988) distinguishes between three different models when it comes to interacting with computer system. These models are (Figure 2.5):

- Design model: is the conceptualization that the designer of the system has in mind. Hence, it reflects what the designer wishes to project to the user.
- User model: it is the model that the user builds of the system whilst interacting with it. It can be defined as the conceptualization that user has of the system image.
- System image: is the image of the actual system, what it represents, and how it reacts to the user's interaction.

It is the role of the designer to bridge the gap between the user model and the system image in order to satisfy the global conceptual model of the system (Newman & Lamming, 1995).

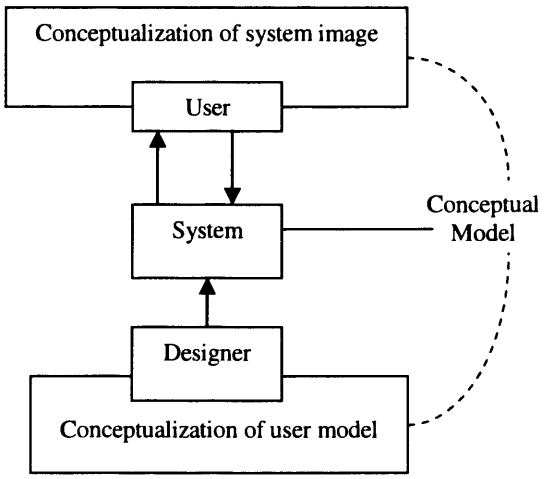


Figure 2.5 User, Designer and System models

Incorrect user models will result in errors being made. The conceptual model reflects the accurate model of the system that the designer intends to reveal. Hence, the ultimate goal is for both the user and the designer's mental models to reflect the conceptual model of the system (Figure 2.5). Norman (1983) characterizes users' models as:

- Incomplete

- Unstable: users tend to forget features of the system they use
- Do not have firm boundaries where similar devices and operations can be confused
- Unscientific: users tend to stick with the ways of doing things
- Parsimonious: users tend to trade off extra physical actions for reduced mental complexity

Mental models are at the essence of users' interaction with the interface, it is through the execution of these models that users act upon the interface. These models are subjective as they differ from one user to the other. In addition, they are non-static as they are susceptible to change and are dependent on users' past experiences.

2.4.3 InfoVis: Domain related models

Ware (2004) describes users' activities when it comes to interacting with InfoVis tools as:

"On the human side, the visualization can act as an extension of cognitive processes augmenting working memory by providing visual markers for concepts and by revealing structural relationships between problem components"

From this quotation in addition to the discussion presented as part of the navigation framework, it can be seen that mental models when it comes to InfoVis literature are related to the domain's externalized visual representation. When users interact with a system and a system's conceptual model does not reflect any of the user's mental models the user starts building new models (Card, Moran, & Newell, 1986). It is an activity that goes into the mind of the user. The visualization activity is seen as that of building an internal interface (Ware, 2004) that cannot be printed or seen by anyone other than the user. It is through this act that users gain knowledge and insight of the externalization. InfoVis is all about the insight that people generate as a result of their interaction, as Card et al (1999) indicate: *"The purpose of visualization is insight and not pictures"*.

2.4.4 InfoVis as an experience

Mental Models within the context of InfoVis, is dependent on the ways in which people make sense of something they interact with. When interacting with visualization tools, users may have specific goals or hypotheses that they would like to examine, or they might interact with the tool to simply gain insight of the domain. As the users interact with the tool, "ah HA!" moments arise, as Spence (2007) describes. How and when these moments are reached differs from one user to the other as they are subjective and dependent on the models they generate of the domain. It is these "ah HA!"

moments that makes them an experience, as they are dependent on past experiences and hence may not be easily observable (McCarthy & Wright, 2004).

The capturing and validation of internal models is a difficult task (Norman, 1983). In addition, it is a controversial one: Rogers et al (1992) claim that merely trying to make people talk about their mental models may in fact affect and change these models, proving their delicacy. Experience is something that happens in the person's mind, it is made out of feelings and emotions that one has. Hence the question here is: how can users' InfoVis experience be scientifically researched? User experience is an emerging topic within the context of HCI which has varying trends and dimensions.

2.5 HCI and the User Experience

Norman (1998) describes user experience as encompassing *all aspects* of users' interaction with a product. The terms *all aspects* makes the study of user experience quite complex and rich, as it incorporates interrelated aspects such as feelings and emotions that are hard to quantify. Even though we can design for experience as Norman (2004) explains, the concept itself is still quite immature as researchers have been attempting to reach a cohesive theory or framework which has yet to be achieved. McCarthy and Wright (2004) offer an account of experience that is related to an individual within a cultural context. From their account, users' experience with technology takes place in the context of a remembered past and an anticipated future. It is expressed through the memories we generate and the stories that we tell others. In order to study user experience within the context of HCI several approaches have been adopted, some draw heavily on cognitive science where the main focus of study is the user e.g. (Hassenzahl, 2001), (Jordan, 2000), (Norman, 2004). Other approaches take more of a holistic phenomenological approach, where experience is seen as the totality of engaging oneself in a relationship with an object (Dewey, 1934). Hence, the focus is on the relationship that one draws with the object of interest, and not just on the user as in cognitive science. Whether the approaches are based on cognitive science or phenomenology, all are concerned with the analysis of sensations, emotions, perceptions and human behaviours (Swallow, Blythe & Wright, 2005).

Due to the multidisciplinary nature and complexity of the concept there is yet to be an agreed upon method or technique. The applied research techniques vary from studies that rely on scenario-based analysis and personas (Swallow et al., 2005), to others that incorporates the study and analysis of emotions and behaviours (Desmet & Hekkert, 2002) such as: facial expressions and physiological

responses (Mahlke & Thuring, 2007). Hassenzahl (2005) differentiates between the approaches by categorizing them into approaches that focus on non-instrumental quality aspects and others that take the roles of affect and emotions into account to better understand people's experiences. Non-instrumental qualities focus on hedonics (Hassenzahl, 2001), aesthetics (Tractinsky, Katz & Ikar, 2000), pleasure (Jordan, 2000) and fun (Blythe, 2004).

Forlizzi and Battarbee (2004) give a more detailed categorization of the approaches taken by researchers in understanding user experience. They break them into three categories: product-centred approaches, user-centred approaches and interaction-centred approaches. Product-centred approaches focus on the qualities and characteristics of the interface. User-centred approaches rely on theoretical models of human behaviours and actions: in other words, they relate to cognitive science approaches. Last but not least, interaction-centred approaches apply try to understand the relationship between the product. For the purpose of this research, the approach that will be relied on is the interaction-centred approach due to the fact this research is interested in understanding the relationship between the user and the tool.

2.6 Conclusion

From the discussion above it was established that users' interaction with InfoVis tools can be viewed as an experience. This is due to the subjectivity of the internal models that users create of the domain. According to the discussion presented in this chapter, the externalization forms an essential component in users' InfoVis experience. However, externalizations are not the only component that affects the experience. According to the motivation of this thesis, which was presented in Chapter 1, the interface is an essential component to users' experiences as users must interact with the interface in order to accomplish their goals. As a result, this research looks at users' InfoVis experiences from a holistic phenomenological perspective, whereby the focus will be on understanding the relationship that is constituted between the users and the tool, an interaction-centred approach (Forlizzi & Battarbee, 2004). In other words, this research looks at the holistic relationship that the user will have with both the externalization and the interface. Users' interaction with the externalization has been discussed in detail in this chapter. Users' interaction with the interface will be discussed in the next chapter and is dependent on the activities that users perform on the interface.

3. Users and the Interface

3.1 Introduction

The interface is an essential part of user InfoVis interactive experiences as users will not able to accomplish their goals unless they interact with it. Studying users' interaction with the interface is not new. In fact it is the focus of HCI research and hence has been thoroughly studied. This chapter focuses on one of the most commonly applied interface interaction techniques, Direct Manipulation (DM) as it is being used by all Graphical User Interfaces (GUI); in addition, it represents the interaction technique adopted by most InfoVis tools. Shneiderman (1983) has laid out the properties of DM interfaces. These properties have been used by a large number of HCI researchers when it comes to identifying and explaining DM interaction styles. These properties, however, are of a high-level nature as they do not explicitly address users' manipulation activities.

Manipulation activities are crucial to users' experiences when interacting with InfoVis tools as they are the activities that users engage with in order to manipulate the device space. The instrumental interaction model (Beaudouin-Lafon, 2000), on the other hand, is a model that explicitly addresses such activities and hence is reviewed as part of this chapter. The goal of this chapter is to complete the discussion raised as part of Chapter 2 from the perspective of the motivation of this thesis in relation to users' interaction with InfoVis tools by concentrating on users' interaction with the interface.

3.2 Interaction Model

Any interaction process, whether it is with the physical world or with the computer system, starts with an underlying goal. After forming the goal the person takes a set of actions with which s/he interacts with the world in order to achieve or satisfy that goal. Norman (2002) categorized the actions that people take in any interaction process into two categories: execution actions and evaluation actions (Figure 3.1). After forming the goal the person manipulates the world, by performing a set of execution actions. As a result of these actions, changes happen to the world, and the person evaluates these changes through a set of evaluation actions. As a result, the user determines whether or not the goal has been achieved. If the goal has not been achieved then the

person takes another set of execution actions, following from which s/he evaluates the world through a set of evaluation actions. The cycle goes on until the goal has been satisfied.

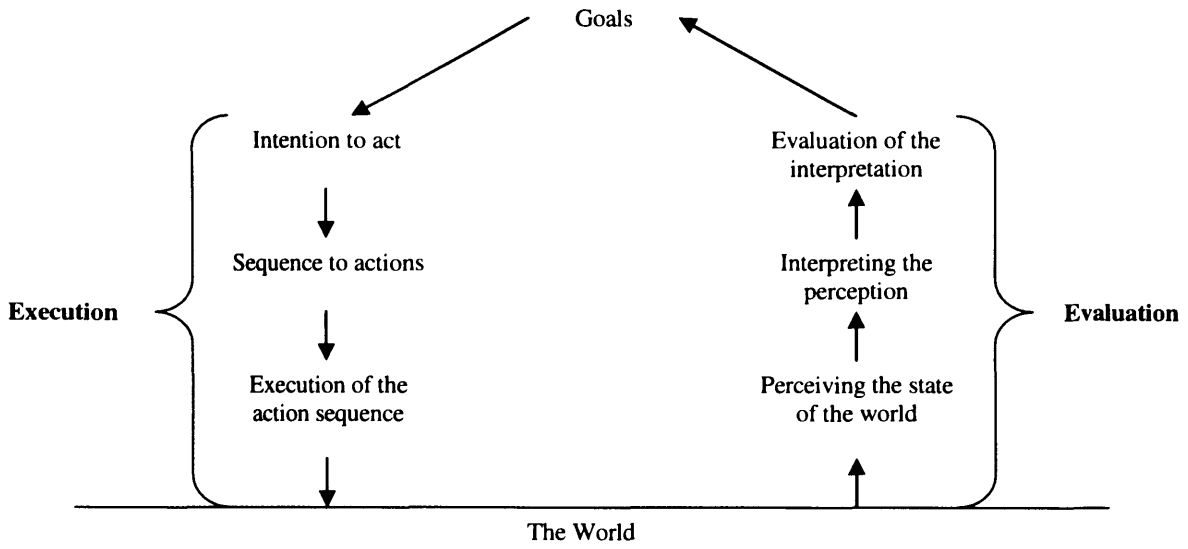


Figure 3.1 Norman's seven stages of action

Norman's model (Figure 3.1) is one of the most influential interaction models in HCI (Dix, Finlay, Abowd, & Beale, 2004). This interaction model is created out of seven stages of action (Norman, 2002):

- Forming the goal
- Forming the intention
- Specifying and action
- Executing the action
- Perceiving the state of the world
- Interpreting the state of the world
- Evaluating the outcome

After identifying and determining the goal, a plan is devised for executing the goal. It starts with forming an intention by which to act upon the world, followed by determining a set of actions and finally executing these actions. With this, the execution phase ends and the evaluation phase starts. After performing the actions, changes occur on the world. The state of the world is then perceived and interpreted. These interpretations are evaluated to determine whether or not the goal has been achieved. If it has not, then the cycle continues until the main goal behind the interaction process has been attained.

Norman uses this model to explain the reasons people make mistakes when interacting with a system's interface. He explains that the problem does not lie on the formation of the goal but on the distance between the user's intentions to act on the interface, and the interface's allowable set of actions, the *gulf of execution*. In addition, it also relies on the ability of the user to identify whether or not the intentions have been satisfied, the *gulf of evaluation*. In other words, the more effort needed by the user to understand and interpret the result of the interaction the less effective the interaction is. In order to achieve interaction effectiveness the gap between the user's intentions and expectations, between the gulf of execution and gulf of evaluation, must be bridged. This represents one of the main challenges in interaction design. Direct manipulation interfaces are interfaces that bridge such a gap by relying on users' natural abilities in addition to providing immediate feedback.

3.3 Direct Manipulation

The concept of Direct Manipulation (DM) goes back to the early 80's with the introduction of the Xerox star, (Johnson et al., 1989). The intention behind it was to develop an office automation system that can be easily learned and used. This system was the first to introduce the 'Desktop Metaphor' where users could directly interact with files via a bit-mapped mouse-driven interface, a detailed account of the origins of the desktop metaphor is found in (Blackwell, 2006). The general goal was to make the computer invisible, so that users could concentrate on the work rather than the computer. It initiated the leap from traditional computer systems that required users to remember text-based commands to Graphical User Interfaces (GUI) where users recognised commands. Direct manipulation interfaces rely on the concept of recognition rather than recall when it comes to the human computer interaction.

3.3.1 Direct manipulation properties

Shneiderman (Shneiderman, 1989) reported that users who were introduced to the concept of DM were very pleased and had positive feelings of their experiences, these are summarized as follows:

- Interfaces can easily be learned by beginners
- Experienced users can execute a wide range of tasks
- Operational concepts can easily be retained
- Little need for error messages
- Immediate feedback allowed users to feel in control by immediately seeing the results of their actions.
- Eagerness to explore the system further

- A general feeling of enjoyment

These positive experiences were used as an indication of the promises that such an interaction style had in store for the ways in which people interacted with computers. From the above feelings Shneiderman identified a set of principles which formed the basis of DM interaction style. These principles are:

- Continuous visual representation of the object of interest in a manner that is meaningful to the user
- Rapid, reversible and incremental actions
- Physical action or presses of labelled buttons instead of complex syntax

These principles represent the most dominant DM principles in HCI literature. Some examples of the references which refer to these principles are: (Baecker & Buxton, 1987), (Newman & Lamming, 1995), (Preece, Rogers & Sharp, 2002), (Dix et al., 2004). From these principles it is evident that the visibility of the object of interest represents the base from which all the other features follow. Users see the object of interest and hence perform actions on the object. As a result, the system responds in the form of visual feedback, in most cases. DM interaction style follows an object-action model of interaction, where the user performs actions on objects of interest in a manner that is direct and natural. DM is the interaction style that is most commonly used by InfoVis tools.

3.3.2 Direct Manipulation in infoVis: Dynamic Queries

The most prominent example of using DM interaction styles within the context of InfoVis is reflected by dynamic queries. Dynamic queries allow for the manual adjustment of one or more data values which would result in an immediate response depicted as part of the visual representation (Williamson & Shneiderman, 1992). Such an interface uses on screen widgets such as buttons, check boxes and sliders to visually represent query components. HomeFinder visualization referred to in Chapter 1 was one of the first InfoVis tools that supported such an interaction paradigm. FilmFinder (Ahlberg & Shneiderman, 1994) is another eminent example that relies on dynamic queries as the main interaction mechanism.

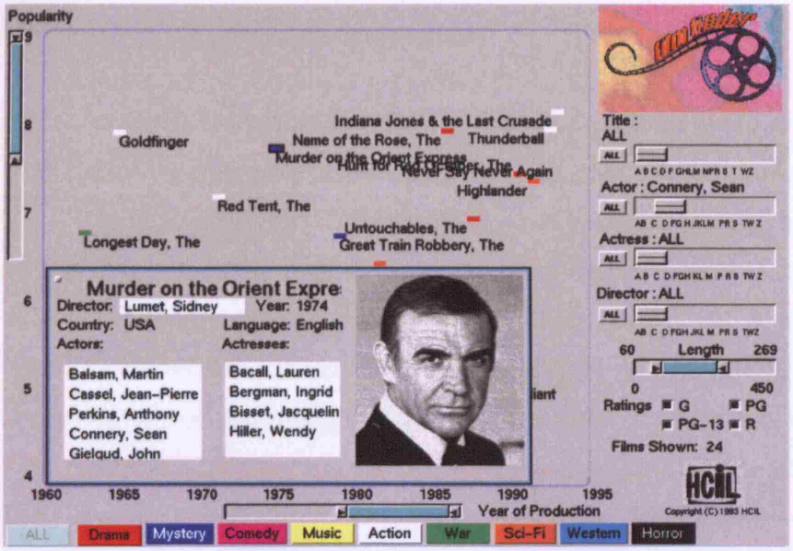


Figure 3.2 FilmFinder (Ahlberg & Shneiderman, 1994)

In FilmFinder (Figure 3.2) users are allowed to explore a large dataset of films. Films are represented as colored squares, where color encodes the genre of the film (e.g. horror, comedy, science fiction, etc). The films are laid out in a scatter plot format, where the horizontal positions indicate the year of production and the vertical positions indicates the popularity of the film. The horizontal and vertical sliders can be used to specify the year and popularity ranges. The controls on the right-hand side of the interface can be used to toggle through information such as: the title, actor, director, length of the movies, etc.

As the user manipulates these controls the visual representation immediately responds by filtering the data and displaying merely the relevant entities. In the example displayed in Figure 3.2 the user has filtered through the visual entities and is interested in a film by "Sean Connery". As the user selects the film, details of the film are displayed. In order for users to manipulate InfoVis interfaces they need to engage in manipulative operations by physically adjusting and interacting with on-screen widgets.

DM has been very successful over the past years. This is due to the fact that such an interaction style takes into account associations based on natural human skills, such as, point, move, drag, etc (Jacob, Leggett, Myers, & Pausch, 1993). Due to the naturalness of this interaction style, users interact with the interface in a comfortable and less stressful manner, reducing associated cognitive load.

3.3.3 Direct manipulation and cognition

When DM interfaces were first introduced their success was mainly related to the specificity of the actions whereby users can easily anticipate and envision the consequences of their actions (Lindsay, 1988). The execution of the commands via DM interfaces is not based on learning specific syntax, but takes the form of actions which are performed by the users on the objects of interest. Hence, users, especially novices, no longer need to struggle between the syntactic and semantic levels of knowledge. To better understand this concept, Shneiderman (1983) gives a brief overview of the syntactic and semantic levels of knowledge, where each affects the human's cognitive load differently. The syntactic knowledge represents low-level commands that the user needs to learn in order to interact with a specific system. These commands need to be memorised; however, they can easily be forgotten if not constantly used. On the other hand, semantic concepts are at higher levels of knowledge. They are normally system independent and can easily be remembered since they are related to general concepts. As users gain experience, they tend to think of using concepts that are most probably system independent, i.e. think within the semantic level of knowledge. This reduces their cognitive processing. Whereas in the case of novice users lots of effort is put into gaining syntactic knowledge before semantic knowledge can be gained.

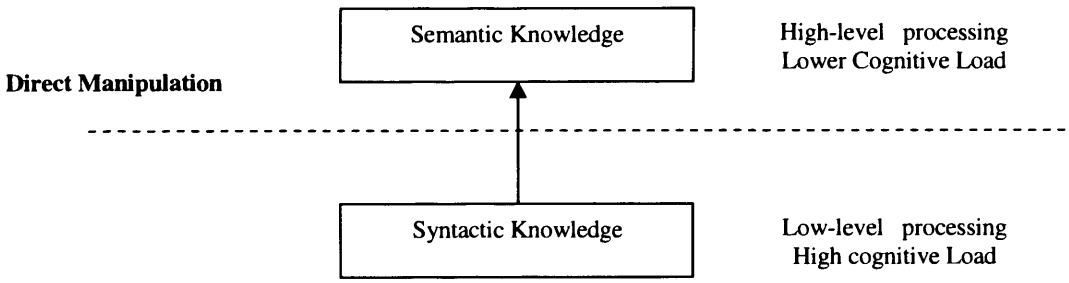


Figure 3.3 Direct Manipulation works at the semantic level of knowledge

When it comes to DM interfaces, due to the visibility of the objects, users, especially novices, do not need to get tangled with gritty syntactic details (Figure 3.3), as they introduce functions that need high level processing by targeting knowledge that is already at the semantic level. Hence, both novice and expert users can work at their level of expertise with little cognitive overhead; where no syntactic errors occur. In addition, with DM interaction style the result of each action taken by the user is immediately visible, hence reducing problem solving load.

Hutchins, Hollan and Norman (1985) define directness as a *feeling* that cannot be quantified or measured. It results from the commitment of *less cognitive resources* whilst interacting with an

interface. Hence, the more the user needs to do to accomplish a task, the less direct the action is. He defines two aspects that result in the feeling of directness, which are:

- The distance between the user's intentions and the actions allowed by the system – bridge the gulfs of evaluation and execution
- The feeling of engagement which results from the feeling that one is truly manipulating the object.

Hutchins et al (1985) emphasise that the origination of the feeling of directness is of utmost importance. They go on to emphasise that we should distinguish between directness that originates from practice and directness that originates from the close semantic coupling between the user's intentions and the actions that are to be taken upon the object of interest since they are acquired differently. Good interaction design is usable not by practice but by good principles, where interfaces need to be easy to learn, effective to use and provide a good user experience (Preece et al., 2002). Shneiderman's DM interaction model is too general and high level to distinguish between the levels of directness. To illustrate this, let us take the example of resizing a window on the screen: the object of interest is the window. There are two general ways in which this can be done: the first is by manipulating the window directly, the second is by interacting with an on-screen widget. In the first, the user uses the mouse to increase or reduce its size by dragging its edges (Figure 3. 4 (a)). In the second, the user interacts directly with the widget, the mouse, to click on the resize button (Figure 3.4(b)).

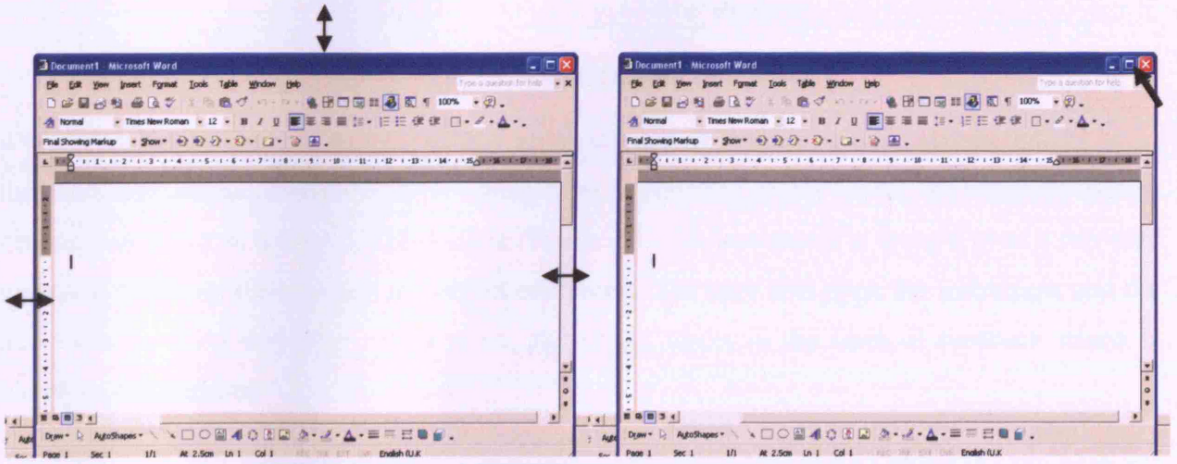


Figure 3.4 Resizing a Window (a) resize the window by dragging one of the edges (b) resize the window by clicking on the resize button

It can be seen that in the second interaction technique, the mouse is used to manipulate the button and not the object of interest. Both these examples are based on a DM interaction style, yet their directness varies. The instrumental interaction model provides a more concrete set of properties that

can address the varying levels of directness by taking into account users' manipulative physical activities.

3.4 Instrumental Interaction

Beaudouin-Lafon (2000) explores the concept of graphical DM interaction styles further than Shneiderman's model. He argues that interaction is a phenomenon that occurs as the user interacts with the computer, and in order to control the quality of the interaction we need to think in terms of interaction and should design for it. Research should move from designing interfaces to designing interaction in order to augment human capabilities. He introduces a new interaction model which he calls the *instrumental interaction* model.

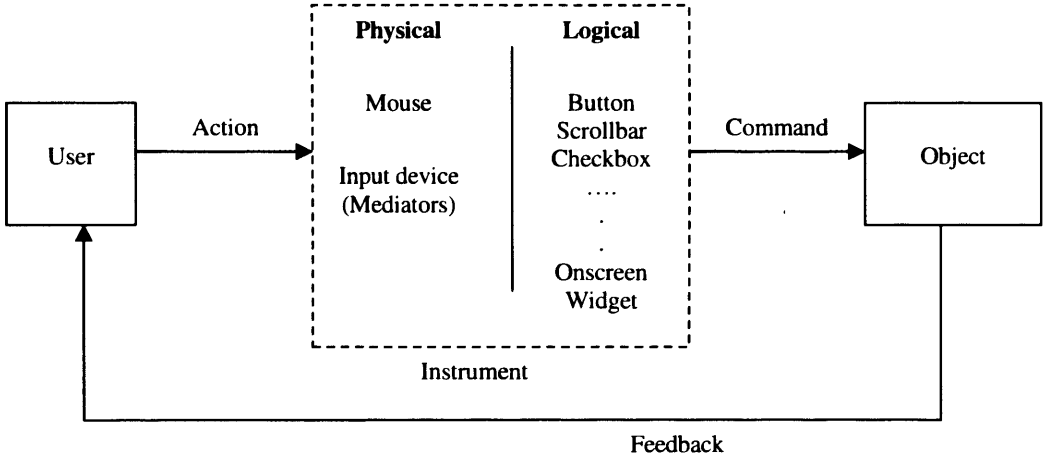


Figure 3.5 Instrumental interaction model

In this model the onscreen widgets and the physical input device are coupled and thought of as an instrument, hence the name instrumental interaction. According to this model, the object of interest is manipulated via an interaction instrument (Figure 3.5). An instrument is thought of as a two-way transducer between the user and the object of interest. The user acts upon the instrument and the instrument issues a command. As a result, the object reacts in the form of feedback which is interpreted by the user.

In the case of instrumental interaction each instrument is tied to a single activity- a command, for example: a scrollbar is used to scroll a document, and a zoom-out button is used to zoom out of a document. In addition, each instrument is made out of a physical part and a logical part. The physical part is associated with the input device and the logical part is associated with the onscreen widget. Instruments are activated as soon as the physical part is linked to the logical part.

3.4.1 Instrumental interaction properties

Beaudouin-Lafon defines three properties of the instrumental interaction model. These properties are: degree of indirection, degree of integration and degree of compatibility. Following is a detailed explanation of each of these properties as they will be referred to in Chapter 6. This is due to the fact that the instrumental interaction model is the model that was used for the design of the manipulative activities of the Academic Literature Domain (ALD) InfoVis prototype.

Degree of indirection

The degree of indirection is a 2D measure which incorporates spatial and temporal offsets. The spatial offset is defined as the distance between the logical part of the instrument and the object it acts on, the object of interest.

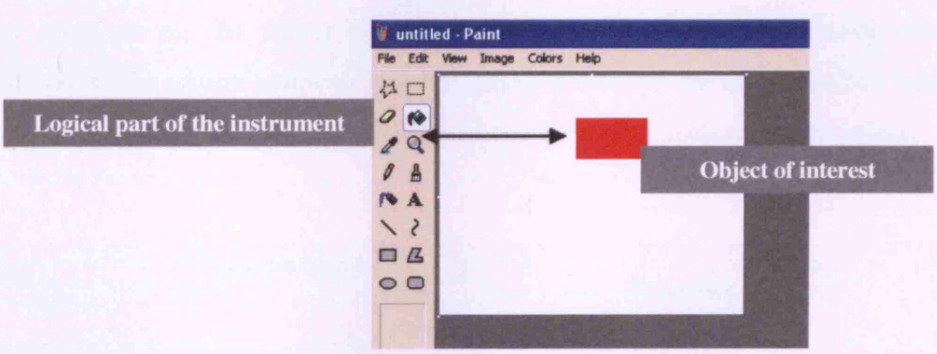


Figure 3.6 Spatial offset: Distance between the logical part of the instruments and the object

For example, Figure 3.6 is a snapshot of a simple paint application, the object of interest is the rectangle and the action that needs to be taken upon the object is the "fill-in" action where the user fills in the color of the object. In order to do so, the user must first select the "fill-in" on-screen widget. In terms of instrumental interaction, this represents the activation of the "fill-in" instrument. After activating the instrument the user performs the action upon the object of interest, which in this case is the rectangle. By simply clicking on the rectangle, it fills up. The spatial distance in this example represents the distance between the logical part of the instrument, which is the on-screen widget, and the object of interest, which is the rectangle.

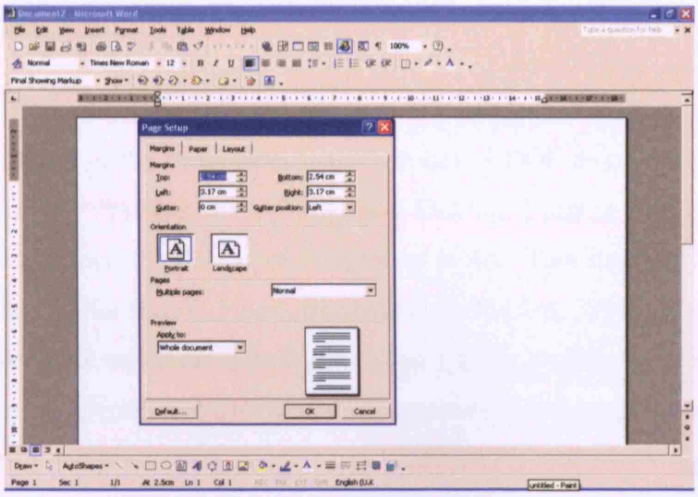


Figure 3.7 An example for temporal offset: Page properties dialog box

Temporal offset is defined as the difference in time between the physical action on the instrument and response on the object of interest. Figure 3.7 represents a dialog box instrument. This instrument has a large temporal offset, since before any of the set properties can affect the object of interest, which in this case is the document, the user must click on the ok button.

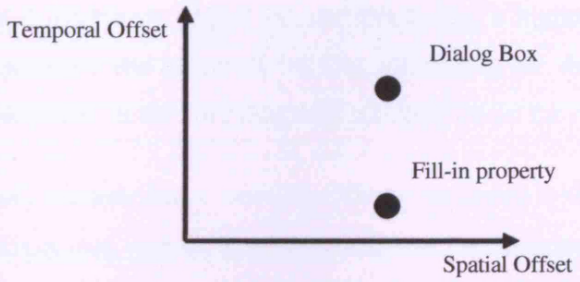


Figure 3.8 Degree of indirection

Figure 3.8 shows the degree of indirection of the examples we demonstrated in this section. It can clearly be seen that they differ when it comes to the temporal offset. In the case of the paint application the effects on the objects of interest, which is the rectangle, occur faster than the effects that occur on the document. In the former, the effects occur soon after the user clicks on the onscreen widget, whereas in the latter situation, the changes do not occur as the user interacts with the logical parts of the dialog box instrument (pull-down lists, buttons, etc): they only occur after the users click on the 'ok' button.

Degree of Integration

The degree of integration measures the ratio between the number of degrees of freedom (DOF) provided by the logical part of the instrument to the number of DOF demonstrated by the physical part of the instrument. For example: a scrollbar has a DOF of 1 and is controlled by the mouse which has a DOF of 2, hence the degree of integration is 1/2. This measure was inspired from Jacob's notion of integral tasks (Jacob, Sibert, McFarlane, & Mullen, 1994). Achieving a degree of integration of 1 is the most efficient. Beaudouin-Lafon (2000) emphasizes that this measure is extremely useful when comparing two instruments that perform similar operations. A button is a 1 DOF logical instrument; it is controlled by a 2D mouse. However when looking closer we identify that the clicking of the button is not performed using the mouse's 2D property, but it is performed by clicking of the top button of the mouse. Hence we say that the selection instrument has a degree of integration of 1 which is very efficient.

Degree of compatibility

The degree of compatibility measures the similarity between the physical actions of the users on the instrument and the response of the object. Beaudouin-Lafon (2000) explains this concept using the following example: dragging an object via the mouse has a higher degree of compatibility than scrolling a document since the object of interest will follow the direction of the mouse, whereas when scrolling a document, as the user drags the scrollbar down the document moves up.

This model takes into account users' activities when interacting with an interface. Through the use of this model interfaces that vary in their directness can be designed. In the context of InfoVis the main activities that users engage with are cognitive activities. As a result, interface-related manipulations should be designed in a manner that would reduce the cognitive load associated with such activities.

3.5 Interaction in InfoVis

When interacting with InfoVis tools, the raw data itself is not the goal: it is the information it conveys. It is important to note that information and data are not equivalent, as Bertin (1983) emphasises. He describes information as being the revelation of underlying relationships between the data. Information is derived from the data as Spence (2001) indicates. By looking at the visually represented data, in other words browsing through the representation, interesting information is revealed.

"Graphing data needs to be iterative because we do not know what to expect of the data; a graph can help discover unknown aspects of the data, and once the unknown is known, we frequently find ourselves formulating questions about the data" – ((Cleveland, 1985) quoted in (Spence, 2001))

It is impossible to determine in advance what can be inferred from the data unless it is examined and re-examined from different perspectives. This exploration, as Shneiderman (1997) puts it, allows users to gain a better comprehension of the data. Exploration can be seen as the process that takes users through the transition from the abstractness of the data to gaining domain related knowledge. Interaction represents one of the major components of visualization tools (Card, Mackinlay & Shneiderman, 1999). It is what distinguishes it from static information graphs (Tufte, 1990). There have been attempts in InfoVis literature to gaining a deeper understanding of the role of interaction within the context of InfoVis e.g. (Yi, Kang, Stasko, & Jacko, 2007) whereby they categorise interaction techniques based on users' intent. This research does not look at the techniques with which users interact with InfoVis tools instead it looks at it in terms of the activities that users engage with in order to execute their goals. Users' activities when interacting with InfoVis can be looked at from the perspective of Payne, Squibb and Howes's (1990) Yoked State Space (YSS) hypothesis, which is a hypothesis that is applicable to all representational devices.

According to the YSS hypothesis users' goals are seen as states in the domain, or goal space. These states cannot be manipulated directly as the user needs to interact with the artefact through operations that would allow the states to be transformed, in the device space. Hence, in order to solve problems in the goal space the user must know how the device space represents the goal space i.e. how it will affect the goal states. As a result, the two spaces need to be yoked.

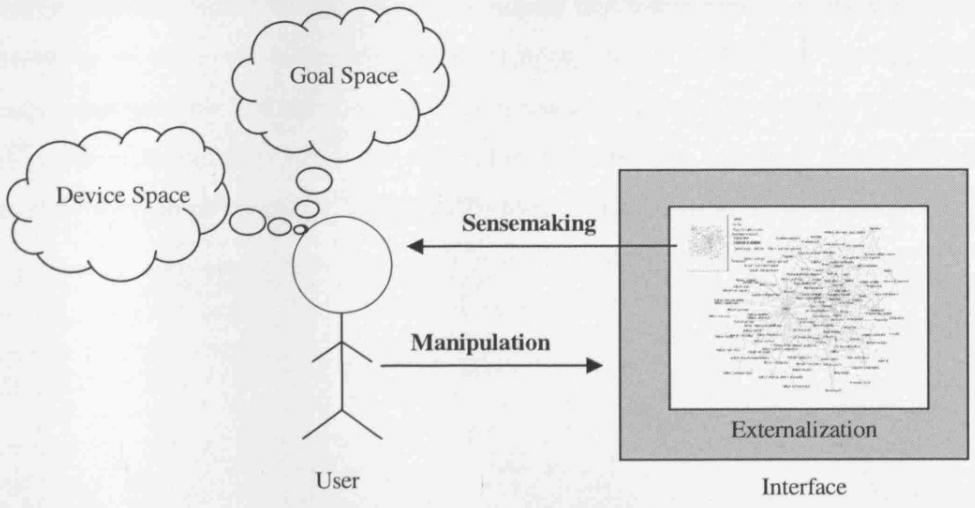


Figure 3.9 YSS hypothesis and users activities

From within the context of InfoVis, which is the focus of this thesis, users' tasks are transformations to the goal space, such as generating overviews, focusing on details, or filtering out unnecessary information. In order to accomplish these goals the user needs to apply device operators to the device space and hence must have a model of the device space and how it represents, in other words affects the goal space. Hence, interface and externalization cannot be separated; they are part of a whole. By looking at users' activities from this perspective when interacting with InfoVis (Figure 3.9) it can be seen that these activities can be categorized into activities that users engage with in order to build domain related internal models (Chapter 2), which will be referred to as sensemaking activities, and activities with which users build and execute interface related models, which will be referred to as manipulative activities. Sensemaking activities take part of the goal space, whereas manipulative activities are part of the device space. Both these activities rely on cognitive processing. The means with which these activities can be effectively designed in order to deliver a positive InfoVis experience forms the focus of this research.

3.6 Conclusion

Interaction is the essence of users' experiences. It is through interaction that users are able to execute their goals and gain knowledge of the represented domain. When users interact with the InfoVis tool they engage in a set of activities with which they make sense of the visual externalizations, and a set of manipulative activities with which they manipulate the externalizations. InfoVis interfaces are mostly designed under the DM interaction model. The power of DM interfaces lies on the directness of users' interaction with the interface. The DM interaction model is very generic as it does not make explicit users' manipulative activities. The instrumental interaction model is based upon the notion that interaction is a phenomenon. In this model, interaction is done via instruments that act upon objects of interest. Hence, it takes into account users' manipulative activities. This model is used as the model on which the design of the ALD InfoVis tool (Chapter 6) is based. However, before going into details of the development and evaluation of the tool, an overview of ALD InfoVis tools is presented in the next chapter

4. Academic Literature Visualization

4.1 Introduction

The academic literature was chosen as an application domain for the visualization tool with which the objectives of this research will be met. The rationale behind the choice of this domain was based upon the motivation of this research: to design InfoVis tools that target the user and not the expert in addition to it providing an accessible user base. Users of this domain are mainly academics that have varying backgrounds and needs, making users' interaction with the academic literature an experience that varies from one academic to the other. These experiences are complex enough in that they would benefit from InfoVis tools. As a result, academic literature InfoVis tools exist. From reviewing InfoVis research, literature visualization tools were categorized into two main categories: Knowledge Domain Visualizations (KDViz) and Information Retrieval (IR) visualizations. However, neither of these categories fitted the prototype needs which are listed as: interactivity of the tool, support of users' varying needs, support of users' conceptual understanding of the domain, and usability of the tool. All of these are essential, as we cannot design for experience if the tool is, for example, not usable and/or does not satisfy users' varying needs. The aim of this chapter is to give an overview of the existing literature InfoVis tools and to demonstrate that these tools do not fit the system requirements of the prototype needed by this research, therefore leading to the design and implementation of an ALD InfoVis prototype.

4.2 Profile of the Required Tool

In order to address the aim of this research, four properties were identified as being essential characteristics of the tool that will take part in this research. These properties are: interactivity, user variance, supports users' conceptual understanding of the domain, and usability. Each of these will be discussed next from the perspective of their importance to this research's needs.

Interactivity

Interactivity is one of the core elements that the visualization tool needs to accommodate since it is through interaction that users are able to manipulate the visualization, in order to accomplish their goals. Users interact with the tool either through on screen widgets or directly via objects of interest, as discussed in Chapter 3. It is not interactivity per se that is necessary, but interactivity that is tailored to satisfy users' varying needs that is needed. This leads to the next property, catering for user variance.

User variance

In addition to interactivity the tool needs to be designed in a manner that satisfies the needs of users. In other words the tool must be designed to target a diverse population of users. It is the users that this research is interested in. Hence, their goals need to be taken into account.

Support users' conceptual understanding

The information the visualization portrays needs to be understood by the users. Hence, it needs to reflect users' conceptualization of the represented domain. Portraying concepts that do not reflect user needs and understandings will make the visualization tool uninteresting, and hence cognitive engagement will be difficult to attain.

Usability

The tool must be usable. This ranges from the clarity of the visual cues and their ability to portray the domain concepts, to the usability of the interface in general. Usability is essential; if the tool is unusable then this will have a negative effect on the users' experiences.

Academic literature, as a domain, fits the requirements of the tool due to its complexity and user variance. As a result, it was chosen as an application domain.

4.3 Visualization and the Academic Literature Domain

As identified by the system profile, the visualization tool needed by this research must be cognitively engaging and highly interactive. The academic literature domain is ideal due to the fact that it is complex in relation to the concepts and information it portrays, and it has a diverse user population which ranges from students to expert researchers each having variant goals. Users of this

domain are members of academic institutions which, in our case, are easily accessible. In addition, this domain is closely related to the digital library work going on at University College London Interaction Centre (UCLIC), my research group, which enables this research to fit within UCLIC's research interests.

This domain represents the literature data within an academic context. It includes information such as: authors, papers, citations, journals, etc. Users of such information are mainly researchers in an academic field since it is important for them to keep track of the literature. In addition to keeping up to date with published research, which becomes a natural activity in their careers, they also need to create a complete and global understanding of the community, how it evolves, and how it relates to other research communities. Academic literature data is complex due to its size. Researchers would need to keep track of thousands of literature items ranging from the authors of the publications to the details and main ideas of each publication. In addition, literature data is complex due to the complexity of the interrelations that appear between the entities. For example: citation trails, where a paper cites another paper which in turn cites another. Getting a global view of such information through text based search engines or tools is difficult. From experience, interacting with literature data can become a cumbersome and time consuming task.

Information visualization is ideal, as a technology, for reflecting this type of information. It is a powerful tool due to its ability to represent large amounts of interrelated data on a single display. It excels over text based systems due to its ability to augment users' cognition through the use of natural perceptual abilities, as discussed in Chapter 2. Visualizations of academic literature domain exist, such as: SemNet (Fairchild, Poltrock, & Furnas, 1999), CiteWiz (Elmqvist & Tsigas, 2004), CiteSpace (Chen, 2004). These are classified into two categories. The first set of visualization tools belong to a specialized subfield of the InfoVis field which is known as Knowledge Domain Visualization (KDViz). The second category of literature visualizations does not belong to a specific InfoVis subfield, but is part of the general InfoVis domain. The general goal that these visualizations tend to accomplish is to assist users in retrieving and visualizing search results in an efficient and usable manner. Therefore, they are categorized as Information Retrieval (IR) visualization tools. An overview of the KDViz will be given first followed by an overview of IR tools.

4.4 Knowledge Domain Visualizations (KDViz)

KDViz are visualizations that represent knowledge of specific domain on the screen. People interested in this knowledge are mostly experts known as 'domain analysts' who look for information such as:

- Understanding the structure of the scientific domains
- Understanding how a domain relates to other domains
- Gaining knowledge of the evolution of a domain
- Understanding the social structure of a domain
- Global views of the relationship between scholarly communities
- Identifying diffusions of research topics or authors

Studying this knowledge is a burdensome task. In addition to the number of documents which the analysts would have to sift through in order to try and make sense of the general picture of the domain, they would also have to keep track of the pace of the information growth. Visualizing this knowledge via InfoVis systems is of great benefit since it would assist analysts in maintaining an overview of what is going on in a domain, and across multiple domains. InfoVis systems assist users in gaining knowledge by visually representing the global picture. The use of InfoVis to visualize domain knowledge is not new. In fact it has become an established research area known as Knowledge Domain Visualizations (KDViz) (Boerner, Chen, & Boyack, 2003). KDViz is emerging as a field. Its goal is to paint a picture of the whole of scientific knowledge. Painting this general picture is not free of problems. The process of painting the general picture is complex since the data needs to be gathered, analyzed and represented visually on the screen.

The development process of KDViz relies mainly on computationally intensive algorithms where developers experiment mainly with existing network reduction algorithms to project the data in an understandable manner. These visualizations concentrate mainly on the projection of the whole rather than on the details, as will be seen in the following examples.

4.4.1 Citation maps

Citation maps and more precisely author co-citation maps are very popular in KDViz. The goal behind these citation networks is to identify the intellectual structure within a domain. The assumption is that if two authors are often cited together by many other authors then they are likely to have similar intellectual interests. When exploring the author co-citation patterns subjects within

a domain are revealed. Many researchers within the KDViz field create and explore such networks for example: Murray et al (2006) and Chen and Paul (2001).

Chen (1999) visualizes an author co-citation network, which was briefly referred to in Chapter 1. The general goal here is to reveal the intellectual structure of the Hypertext domain. Author co-citation patterns were extracted from documents which included ACM Hypertext conference proceedings (1987-1998).

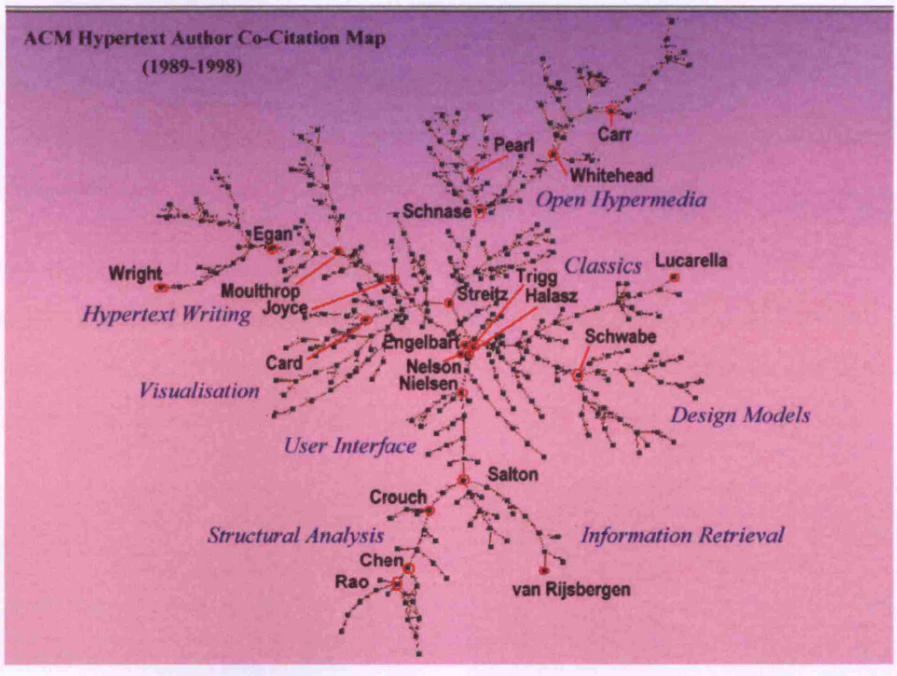


Figure 4.1 Author co-citation map (Chen, 1999)

An overall author co-citation map was generated (Figure 4.1) in order to give a global insight on how the field is structured. In addition, three maps were generated each highlighting a different period: 1989-1991, 1992-1994, 1996- 1998. This was done in order to identify emergent trends of research across the hypertext research area. Generating various maps of the same information is common practice in the field of KDViz. The maps were automatically generated using Latent Semantic Indexing (LSI) (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990) and PFNet (Schvaneveldt, 1990) as analysis and structuring tools. In order for an author to be included in this analysis, the author must have more than five citations in the ACM Hypertext proceeding collection. The analysis of the networks focused on citation interrelationships among authors. From here it can be seen that the projected map does not reflect straightforward relationships since it has gone through reduction and ordination algorithms. Just by looking at the author co-citation map

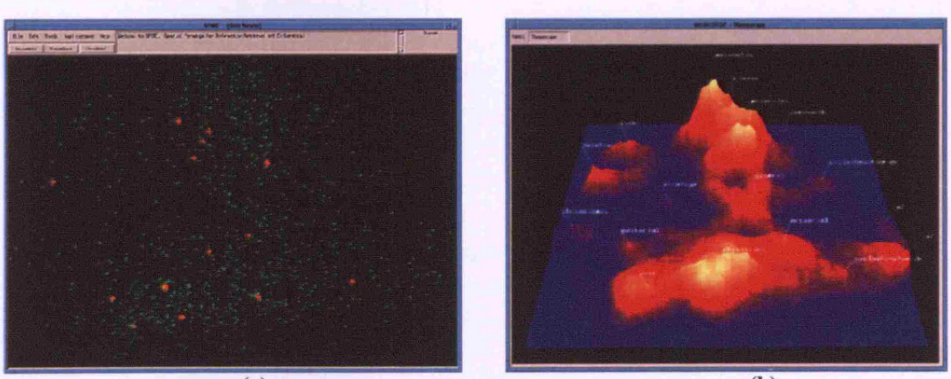
(Figure 4. 1) it would be difficult to understand. The same applies for most KDViz. The concepts behind the map generation process must be explained before it can be understood.

4.4.2 Galaxies and Themescapes

Galaxies and themescapes (Rennison, 1994) (Wise et al., 1995) are visualization techniques that are closely related to visualizing documents, in other words text. The idea behind visualizing text is to give it spatial characteristics which assist in the process of analysing and browsing it. Text visualizations have multiple goals which can be summarised as:

- Similarity between documents grouped in clusters – Galaxies
- The revelation of generalized semantic structures and thematic patterns between documents - Themescapes

SPIRE (Wise et al., 1995) is a seminal text visualization tool. It was developed to assist in the retrieval and exploration of large document corpora. Two visualizations were developed as part of the tool, each representing a different aspect of the text documents, Galaxies and Themescapes. Each offers a different perspective of the same data.



(a) (b)

Figure 4.2 Galaxies (a) and ThemeScapes (b) visualizations (Wise et al, 1995)

Galaxies

Galaxies uses a 2D scatterplot representation of the documents. Each document is represented as a dot in the universe of documents (Figure 4. 2 (a)), hence the name, galaxies. Similar documents are close to each other whereas different documents are further apart. The similarity measure is based on the similarity of the content which is calculated according to the frequency of occurrence of particular words in a document. The corpus clusters are based on the terms that described them.

ThemeScapes

ThemeScapes is a text visualization, like Galaxies. However, it represents documents from a different perspective. It is a 3D representation of document corpora (Figure 4.2 (b)) with the goal of communicating the themes found within the corpora. The representation takes the form of a relief map of a natural terrain. The mountains represent the most dominant themes, whereas the valleys represent weaker themes. Hence, users of this visualization can gain an understanding of the most common themes without having to go through the documents in detail.

4.4.3 Self Organizing Maps (SOM)

Self-organizing maps (SOM) is another important representation technique that some developers rely on to represent literature information. Lin et al (1991) were the first to adopt SOMs and specifically Kohonen maps to visualize document spaces. Kohonen SOMs (Kohonen, 2001) are based on neural networks principles. It is a learning algorithm which produce feature maps very similar to those occurring in the brain.

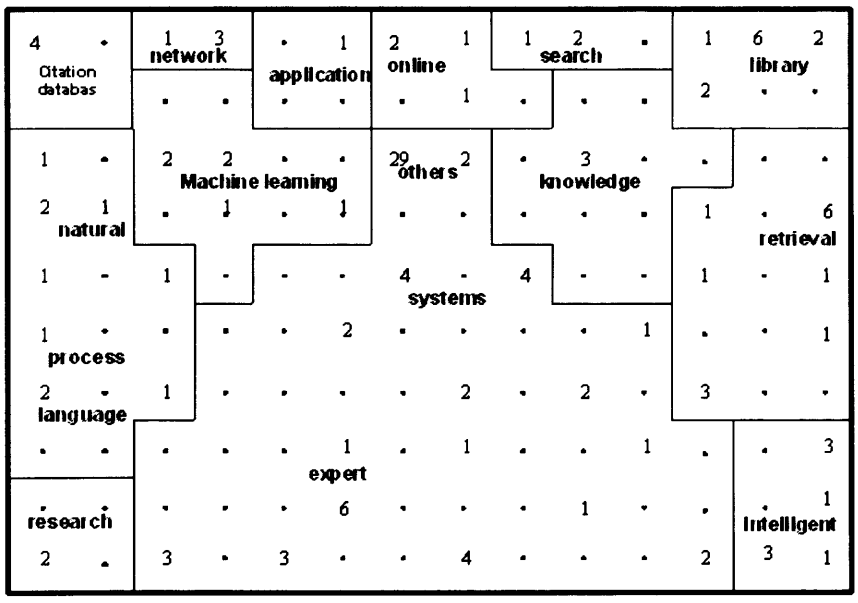


Figure 4.3 SOM semantic map of AI literature (Lin et al, 1991)

The map is divided into concept areas which are automatically generated from the data. The position of the nodes, size and neighbours are determined by the input data. Figure 4.3 represents one of the first examples of literature SOM (Lin et al., 1991). Lin used Kohonen maps to represent the semantic structure of 140 AI documents. The numbers on the visualization represents the number of documents that will be mapped to each node. The difference between this map and the

ThemeScape view is that in addition to providing a global view of the documents it provides content details as the individual documents are represented which will allow browsing. This type of representation is not only used to represent similarities between the semantic structures of documents, but has been also used to represent author co-citation information (Lin, White, & Buzydlowski, 2003).

This illustration of KDViz did not mention users, as users are not part of the development process of these tools. In fact, in most cases, the developers are themselves the users. They are the ones that identify the trends and extract the concepts out of the representations that they create e.g. (Chen, 1999) and (Chen & Hsieh, 2006). Developers, who are themselves the users of these tools, are interested in the presentation of the whole and not the details. However, it is details that we, as academics, are interested in. This leads to the other category of academic literature visualization tools, which are the Information Retrieval (IR) tools; these tools focus on the presentation of the details.

4.5 Literature IR Visualizations

Literature IR visualizations represent the second category of literature visualizations. The visualization tools in this category assist users in searching for and retrieving literature data. More precisely, these tools assist users in better understanding and browsing search results. The tools concentrate more on the details of the literature domain rather than the *whole*. Unlike KDViz, literature per se is not what the IR developers concentrate on. Literature in this case is merely a domain that they use to reveal the ability of the developed visualization tools, meaning that there is not a tight coupling between the domain and the tool. The same visualization can be used for data that is not necessarily related to academic literature.

From reviewing literature in this category the notion of the *users* was evident, which was not the case in the KDViz literature. Usability studies hold an important part in the development process of these tools. Following is a brief description of three seminal visualization tools. Each subsection takes the name of the visualization tool it portrays. This is done in order to emphasise the fact that in this category it is the tool that matters more than the underlying data.

4.5.1 Butterfly

Butterfly (Mackinlay, Rao, & Card, 1995) is a 3D interface to the DIALOG's Science Citation database which is accessible via the internet. It is built around the notion of an *Organic User*

interface meaning that the representation grows automatically depending on query results. Articles are represented as butterflies; each butterfly has a left and right wing, where one wing provides links to article references and the other represents links to article citers (Figure 4.4). By accessing the wings users can navigate from one butterfly to the next.

Focus groups performed with librarians indicated that this interface would be of assistance to them. However, reading their report it was not clear in which ways it would be so. It was also stated that efficient searches were performed by users in less that 30 min of training compared to the regular DIALOG interface which needed 6 hours of training.

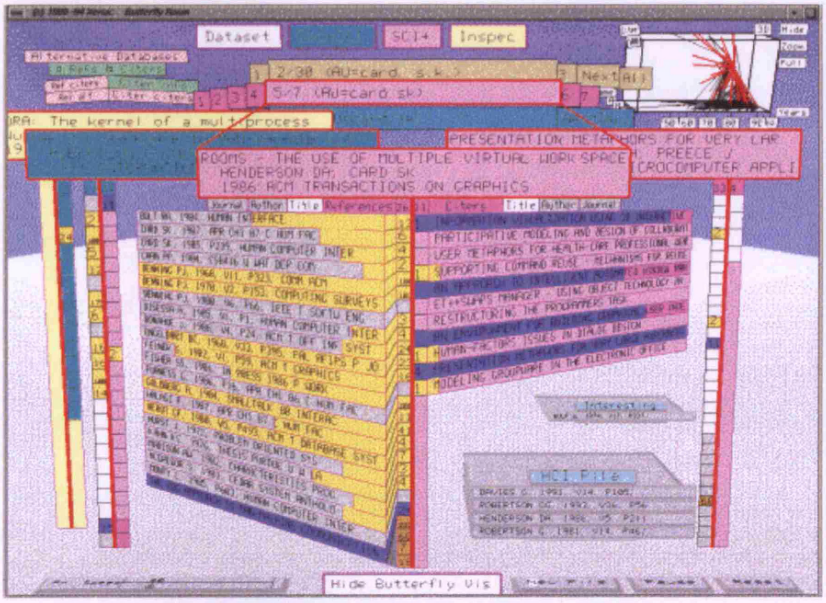


Figure 4.4 Butterfly: Organic user interface (Mackinlay et al, 1995)

4.5.2 Envision

Envision (Nowell, France, Hix, Heath & Fox, 1996) is a multi-media interface to a computer science digital library used to display search results. The goal was to create a user-centred product. Nowell et al determined users' needs by asking 12 participants questions about the ways in which they used information technology sources and what they wanted to see in electronic tools of the future. From here user requirements were identified. A scatter plot graph model was used to represent the research results (Figure 4.5). Individual documents were represented in the form of icons on the graphic display. Users were given the freedom to manipulate semantics of the displayed document icons, such as size, shape, etc. As the users clicked on a document a bibliographic summary was represented in the bottom window.

Usability studies have been conducted to test whether users could understand the displayed results and locate the desired documents. However, these studies concentrated mainly on the visual representations and did not capture whether or not the tool was able to meet the requirements which can be summarized as:

- The ability to identify patterns and trends in the literature
- See connections that were not visible with current tools
- Locate highly influential work etc.

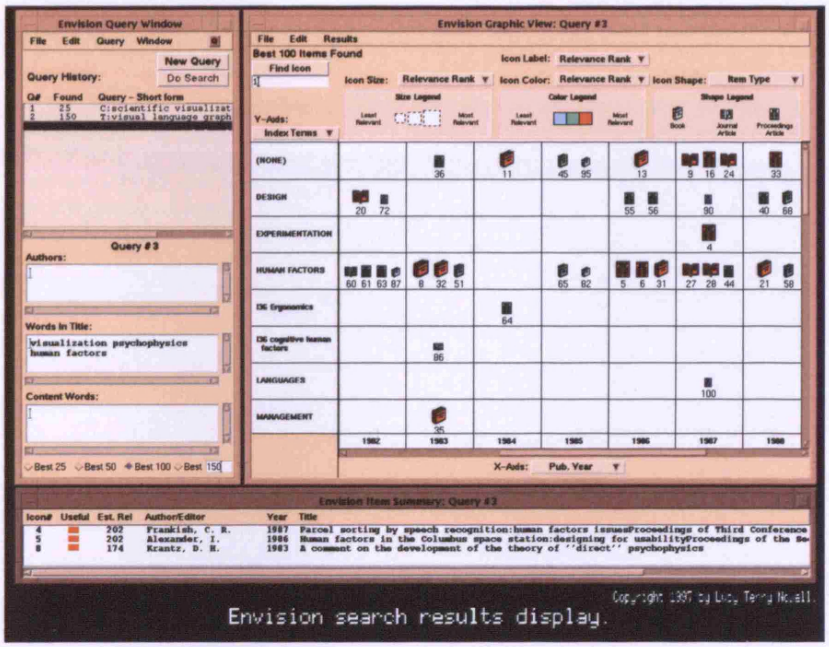


Figure 4.5 Envision (Nowell et al, 1996)

4.5.3 GRIDL: Graphical Interface for Digital Libraries

In GRIDL Shneiderman, Feldman, Rose, and Grau (2000) apply the notion of hierarchical axes which they refer to as hieraxes. The idea was to combine the power of hierarchical browsing and 2D visualizations. The focus is on large search results which may include up to 10,000 items. GRIDL is a tool which, like the previous one, represents search results. It uses the idea of categorical groupings. Documents are categorized and grouped in a grid like interface, which can be applied to a digital library of any sort, and not just the ones that relate to academic literature. The visualization was tested with a digital video library, a legal information system and a computer science library. This overview will concentrate on the computer science literature representation since it is related to the goal of this chapter, which is the visualization of academic literature.

GRIDL (Figure 4.6) was used as an information retrieval system for the computer science department library of the University of Maryland. The system uses the ACM Computing Classification System. All similar items which fall within the same category are compressed with their labels minimised. As the users select a group of items, the details are displayed in the details window on the right. The color of the document represents its type, which in this case can be: book, PhD Dissertation, Proceedings or technical report. Users are able to see overviews through the color coded dots or bar charts arranged in the grid, which is organized by familiar labelled categories. Usability studies concentrated on testing the tool's efficiency when searching for specific papers. As in the other examples they concentrated on the tool and not on the data per se.

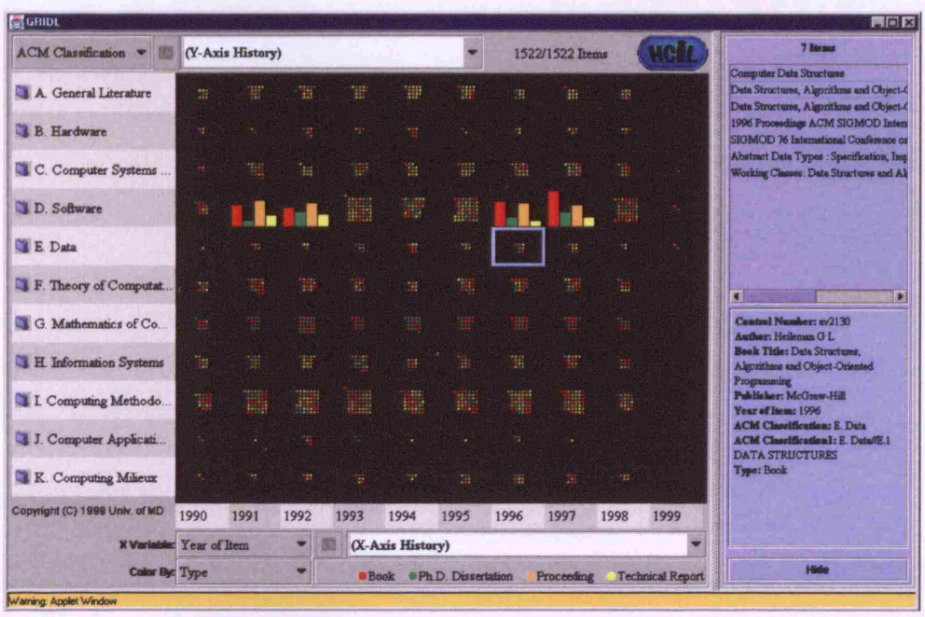


Figure 4.6 GRIDL with the ACM Computing Classification system (Shneiderman et al, 2000)

As described in this section, IR visualizations are visualizations that assist users in browsing search results. Literature data is used as an application domain; however literature is not the goal per se. One of the advantages these visualizations have over the KDViz area is that they take the users into account. Neither IR InfoVis nor KDViz tools fully fit within the context of the system profile set by this research (Section 4.2), as explained next.

4.6 Academic Literature Visualizations and the Profile

From the previous overview given on the existing InfoVis tools neither of these two categories (KDViz and IR tools) complies with the visualization profile (Section 4.2) required by this research. Following is an explanation as to the reasons for such from the perspective of each category.

4.6.1 KDViz

In KDViz literature the domain is the core concept around which these visualizations are built. Lots of effort has gone into finding ways to analyse the data and represent global views of the literature domains, which reflects information such as: evolution of a field, intellectual structure of a field, how a domain relates to other domains, etc. By comparing the properties of these tools with those of the system profile (Section 4.2) it was determined that they do not fit the profile.

Interactivity

These visualizations are not interactive in the sense that this research is looking for in an InfoVis tool. They are complex and hence cognitively engaging. However, they are less interactive when it comes to interface related manipulations. This is due to the high computational power needed to generate these visual representations in addition to the type of information they aim to convey.

User variance

Users of these visualizations are domain analysts who have specific goals. It is according to these goals that the visualizations are built. Generally speaking, domain analysts seek a representation of the whole. They are experts and this research is interested in non-specialist users.

Support users' conceptual understanding

Although there has been no evidence in the literature of any user studies where user needs are gathered, users of these visualizations are expert users, which in most cases are the developers themselves. Hence, it might be argued that the generated visualizations support their conceptual understanding.

Usability

Another important factor is the usability of the tools. From reviewing KDViz literature most of these tools have not been user tested. This might be due to the fact that the developers are themselves the users.

4.6.2 IR Literature Visualizations

The IR tools examples presented in this chapter have shown that the design of the externalizations of these tools does not stem from the literature domains as it did in KDViz. However they seem to fit the system profile set by the needs of this research better than the KDViz.

Interactivity

These visualization tools are very interactive. The user manipulates these visualizations by clicking on on-screen widgets, such as: buttons, sliders, etc.

User variance

These visualizations do not target experts as do KDViz tool. The audience are people that are interested in finding and browsing search results. This means that users of these visualizations might have varying goals and as a result would need to manipulate the visualizations to accomplish their varying goals.

Supports users' conceptual understanding

Although in certain cases, as seen in Envision (Section 4.5.2), users' needs are gathered. But this, when performed, merely is reflected by a requirements gathering study and not an understanding of users' conceptualization of the literature domain. This might be due to the fact that literature, as a domain, is not the goal. Hence, it cannot be asserted that the domain's visual representation fits with users, research academics, needs and understandings of the academic literature domain.

Usability

Most of the systems developed under this category go through a series of usability studies. However, we noticed from reviewing literature related to the development of these tools that these studies concentrate on the usability of the features of the tools and does not concentrate on whether or not these tools fit within the domain requirements per se, i.e. they mainly concentrate on the usability of the interface.

System Profile	KDViz	IR Visualization
Interactivity	No	Yes
User variance	No	Yes
Conceptualization of the domain	Might	Not necessarily
Usability	No	Yes (tool but not domain)

Table 4.1 KDViz vs. IR Literature visualizations based on the system profile

Table 4.1 clearly illustrates the comparison between the properties of both: KDViz and IR visualization tool according to the devised system profile (Section 4.2). It is evident that neither KDViz nor IR visualizations totally fit our needs. However, as illustrated in Table 4.1, IR tools fit the profile better than the KDViz tools. However, when it comes to the usability and users' domain related conceptualization these needs are not totally satisfied.

The backbone motivation of this research is based around the fact that InfoVis is an experience that is affected by both the visual engagement and physical interaction. Hence, every detail which affects this experience should be taken into consideration, starting from the requirements gathering and ending by the usability studies. The literature domain InfoVis tool needs to express the requirements of the users, and the usability studies must reflect the quality of the experience which includes the usability of the tool and its ability to satisfy user requirements and conceptual understanding. Since no tool was found that fitted completely with the needs of this research the decision was to build a tool that would fully satisfy these needs.

4.7 Conclusion

This chapter identified the reasons academic literature was chosen as the domain that is to be represented in the ALD InfoVis tool. The domain was chosen due to its complexity and user variance. These, as indicated, guarantee the interactivity of the tool. Interactivity of the visualization is the core around which the entire research revolves. Academic literature has been visualized by many visualization tools. Some of these tools paint generalized pictures of academic domains (KDViz). Others are used for IR purposes. KDViz tools analyse the data via highly computational algorithms. The generated visualizations satisfy specific goals of an expert population of users, are not interactive and usability studies are rarely conducted. On the other hand, literature IR tools are highly interactive, and have a diverse population of users. However, they lack in their support of users' conceptual understanding and the specificity of usability studies both of which are crucial for the InfoVis user experience. Since none of the existing tools satisfy our profile, an ALD InfoVis tool was built. This tool was designed on the basis of a qualitative study conducted with researchers to try and capture their literature domain sense making experiences and activities. The following chapter gives a detailed explanation of that study.

5. Requirements: Capturing Users' Academic Literature Experiences

5.1 Introduction

Academic literature reflects information of authors, publications, and the relationships that arises between them such as collaborations and citations. Researchers are constantly interacting with such a domain for various reasons for example, familiarizing themselves with the history of a specific research problem, generating an understanding of the ways in which a specific domain has evolved over time, or identifying the latest innovation that relates to a specific research question. InfoVis tools exist to assist researchers in navigating, searching and making sense of their literature domains, where the data is visually represented. As presented in the previous chapter, these tools are limited when it comes to their interactivity and their consideration of users' conceptualization of the academic literature domain. Hence, a prototype of the Academic Literature Domain (ALD) needed to be built as part of this research. However, prior to building the ALD InfoVis tool a requirements study was conducted.

The requirements generation study took the form of a qualitative study where Grounded Theory (GT) was used as the method for analyzing the data. Conducting the requirements study in such a manner has assisted in tapping into researchers' academic literature experiences by generating a high-level conceptualization of the ways in which researchers made sense of such a domain. This qualitative analysis, which represents the main focus of this chapter, has resulted in the generation of a high-level descriptive theory.

5.2 The Study

The study was based on semi-structured interviews conducted with a total of eight researchers. The focus of the interviews was about users' experiences interacting with literature as part of their daily research activities. Following is a detailed description of the study which incorporates the aim and format of the study in addition to the participants' background and study procedure.

5.2.1 Aim and objectives

The aim of the study is to generate the requirements of the ALD InfoVis tool, where the focus is on generating an understanding of the different ways in which researchers make sense of, work with and perceive their literature domains. It is these strategies that would influence the design rationale of the tool. This is due to the fact that the ALD InfoVis tool aims at assisting users in making sense of the academic literature domain in a manner that is natural to them and that relies on their past experiences and knowledge, their conceptualizations of the domain. In addition, the study also aims at gathering enough information to determine the different literature entities that researchers work with, as it is these entities that are portrayed as part of the ALD InfoVis tool's visual externalization.

5.2.2 Study design

Researchers are the main audience this study targets since they are the primary users of the literature domain. In order to get the intended high level understanding of the problem at hand, information needed to be gathered from researchers of varying experiences and knowledge of the domain in which they are working or proposing to work. Due to the type of information needed for the study, semi-structured interviewing was used as the data gathering tool. Since it is a fairly open and flexible framework it provides the opportunity to learn additional relevant information not previously known.

5.2.3 Participants

In total, eight interviews were conducted with researchers of varying experiences (ranging from an experienced professor to a first year PhD student) in the fields of psychology and HCI, as can be seen in Table 5.1. It is important to note that the participants were chosen depending on their experiences and the number of years they were doing research. As the analysis was going on it was identified that junior researchers were better at explaining the processes with which they made sense of their literature domains in comparison to more senior researchers as senior researchers are well aware of their domains and have generated concrete conceptualizations. Hence, their interaction with literature mainly focuses on them looking for specific publications. As a result, more junior researchers (PhD students) were interviewed as seen in Table 5.1.

Participants	Research Focus	Research Background
P1	HCI	2nd year PhD Student
P2	HCI	3rd year PhD Student
P3	HCI	Professor (17 years of doing research)
P4	HCI	1st year PhD Student
P5	Psychology	2nd year PhD student
P6	HCI	3rd year PhD student
P7	Psychology	1st year PhD student
P8	Psychology	Research Fellow (8 years experience)

Table 5.1 Participants research backgrounds

5.2.4 Materials

Materials that were used during the interview were a Sony mini disk recorder (MZ-N1). Participants were interviewed in an office like setting where they were seated on a chair with the researcher sitting across from them.

5.2.5 Procedure

The interviews started with asking the participants to talk about their daily experiences interacting with academic literature, where the focus was on the ways in which they made sense and familiarized themselves with literature in addition to the main problems that they were encountering. The information that the participants provided during the interview guided the questions that were asked during the interviews. Each interview lasted for about 45 minutes. A complete list of the questions asked can be found in Appendix A. It is important to note that these questions are a generalization of the questions asked during the interviews, since questions varied from one interview to the next. Interviews were transcribed and analyzed using GT (Strauss & Corbin, 1998).

5.3 Method: Grounded Theory

GT was developed in the area of the social sciences as a means of theory development. Within the context of HCI, GT has been used in situations where the researcher needs to generate an understanding of a phenomenon, whereby this understanding leads to the formation of a theory. The GT approach is a bottom-up approach where a high-level theory is generated form the details of the data. A thorough account of GT is provided in (Strauss & Corbin, 1998). Within the context of HCI practice GT approach primarily involves the collection and analysis of data. This data may

represent interviews or transcriptions from users, collected during the course of requirements gathering, design and/or usability testing.

The researcher starts the analysis process by assigning meaningful codes, *open codes,* with the aim of generating categories of data. In GT categories represent the pillars of theory development. The categories are drawn from associations of information within the data itself in the form of recurrent themes. For example, during interviews, many participants may speak of their research community as being one of the first places where they would look for literature. Similarities among their descriptions may point toward attributes of common academic literature familiarization strategies.

Drawing from this data, the researcher starts to unite these common themes to form a category. The process continues where various categories starts to emerge from the data. The open codes are created, edited and refined until the researcher determines that further analysis will no longer reveal additional information, i.e. a *saturation point* is researched. The *open codes* are then collected where interrelations are determined through a process known *axial coding*. From these activities, the researcher develops an interpretation of the phenomena at work, from which theoretical propositions can be made. GT was used as the main analysis method of the requirement gathering study. A saturation point was reached after a total of eight interviews. This rapid attainment of saturation is unusual in GT but may reflect the very concrete attributes of what constitutes literature, and the broad agreement of how to approach literature in research, at least across the areas of research represented by the interviewees.

5.4 Process of Evolution

Before going into the details of this study and the resulting generated theory it is important to emphasize the fact that at the beginning of this study no specific hypothesis was formulated. However, the study had a clear goal, namely to determine how users familiarize themselves with the academic literature domain. As indicated, eight interviews were conducted before saturation was reached. The interviews were not conducted back to back, but were separated by analysis in which the data from the most recent interview was assessed against provisional findings to date, to identify where the data further supported existing findings, appeared to contradict findings to date, enlarged upon findings or raised new questions. Within the usual practice of GT, the first interview was exploratory; probing the literature experience in general and how important literature is to the researcher. The emphasis in this interview was on the process that the researcher went through in order to find the intended literature and how such a process changed

with time; this led to the discussion of a few high-level concepts, such as the sense of community. This interview was transcribed. The second interview covered similar issues. Due to the use of semi-structured interviewing, the questions asked in each interviews varied, as the interviewer responded to directions taken by the interviewee. An overview of planned questions can be found in Appendix A as part of the initial stage sample list of questions. This interview was then transcribed. Both transcripts were thoroughly analyzed. This analysis yielded a preliminary picture of the different entities that researchers used to locate literature and the processes that researchers went through in order to find the literature. But most importantly, it started to point to the high-level conceptualizations that users generate as they are working with literature: concepts such as the sense of community and influence started to emerge.

The next four interviews, as well as looking at the low-level process details, explored researchers' conceptualizations of the literature domain in more detail, and whether or not these concepts differed, and on what grounds. These four interviews were all transcribed and thoroughly analyzed. The analysis process also looked back at the interviews of P1 and P2 and further analysis was conducted. This resulted in a clear picture of the literature conceptualizations and the process that researchers went through to familiarize themselves with it. In addition, it pointed to ways in which researchers' background and experiences affected these processes and conceptualizations; an overview of the revised semi-structured interview protocol in Appendix A as part of the intermediate sample list of questions. By the time six researchers had been interviewed, the process and set of concepts appeared to be stable; that is: the sixth interview did not introduce many ideas that had not already been identified in earlier interviews. To confirm this, two further researchers were interviewed, a novice, P7, and an experienced academic, P8. The interviews concentrated mainly on the generated literature concepts and tried to determine how users' backgrounds and experiences affected their conceptualizations. The last two interviews were transcribed and analyzed, an overview of the revised semi-structured interview protocol can be found in Appendix A as part of the final sample list of questions. This analysis process was iterative as it looked back at all the other interviews. From this analysis a high-level theory was generated, as discussed next.

5.5 The Underlying Story

GT assisted in developing a descriptive theory from which the general literature domain sensemaking underlying story was revealed. As the details of forming a grounded theory can be

quite complex, it is useful to describe the overall story of the theory before giving the fuller details that make up the basis for the theory.

Researchers are constantly working and interacting with their literature domains. The information about a domain is strongly related to literature data such as the authors and their associated publications. Thus, a domain is quite simple in relation to the entities it incorporates yet a vast amount of complicated interrelated knowledge can be gained.

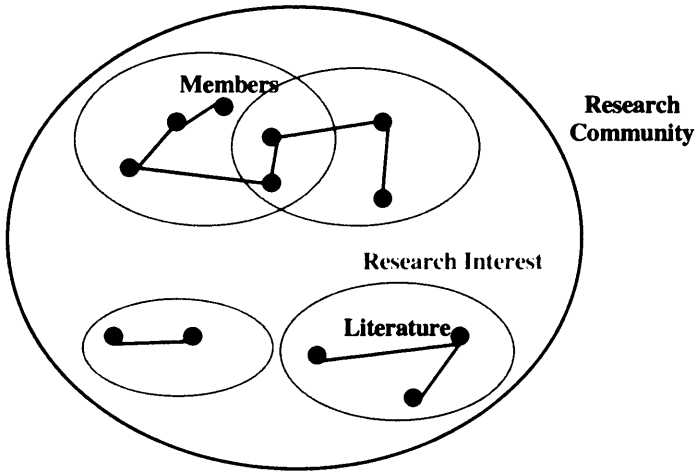


Figure 5.1 Overview of the literature knowledge domain

This study revealed that the sensemaking process of one's literature domain starts with trying to determine who the members of the community are and their associated research interests. The community can be seen as a globe that surrounds its associated entities which represents the members, their interests and the literature they produce (Figure 5.1). It is the community that forms the primary source of the literature domain sensemaking process.

Various research interests exist within a community, each embedded with its members. Members of the community collaborate with one another to produce knowledge, which is reflected by the literature itself. It is the work that goes into these pieces of literature that results in the advancement of knowledge, and hence the development and evolution of the specific research domain. The process of understanding one's literature domain results in gaining vast amounts of knowledge. Some of this knowledge is quite explicit and direct, such as who collaborated with whom on a piece of work, whereas some is more implicit and subjective such as who is influential in a particular domain, or what piece of work or idea changed the course of a field's development, etc. The understanding of one's literature domain is one of the key phases researchers go through as part of

their careers. It is through this understanding that they get familiarized with the research domain to which they belong, gain knowledge of seminal work in the area, and get ideas for their own research. It is this understanding that assists them in participating in the overall advancement of research. As P7 indicates:

> *"...I think that this [familiarization process] is quite the whole point in a way, we are trying to* ***build up some picture*** *of um you know an understanding of whatever our area is".*

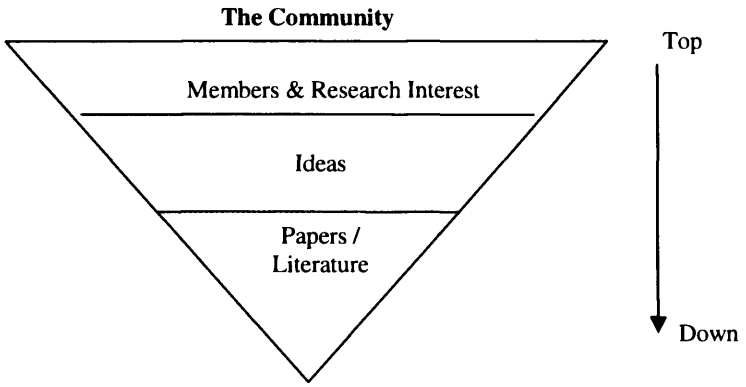


Figure 5.2 Understanding of one's literature domain

Figure 5.2 shows that the understanding and sensemaking process of one's literature domain starts with knowing who the members of the community are, in addition to their associated research interests; more importantly, it relates to the ideas that researchers generate of their domains. The papers, in other words pieces of literature, represents the lower level concrete entities that researchers interact with in order to gain information which eventually leads to gaining knowledge of their literature domains.

5.6 Analysis

Having given a general feel for the theory of the literature domain sensemaking process, the discussion turns to the detailed findings of the interview analysis. GT allowed for a number of categories and associated relationships to be identified through an iterative process of analysis using open and axial coding. These results are further interpreted to reveal a close relationship with the literature domain understanding process.

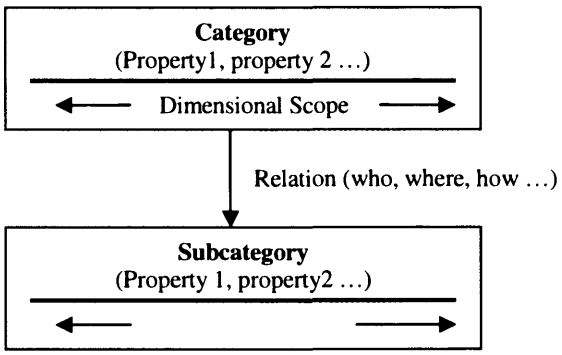


Figure 5.3 Category diagram

From this point onwards the category description will rely on diagrams such as the one presented in Figure 5.3. Each diagram expresses a category and its associated subcategory/s. Subcategories further explains a category by giving it additional specification and depth by explaining when where, how...etc a phenomenon occurs (Strauss & Corbin, 1998). Categories and subcategories are made out of a set of properties, which reflects its characteristics, and a dimensional scope, which represents the range along which the properties vary. These diagrams assist in giving a global view of each category. In addition to the diagram, quotations extracted from the interviews will be used throughout the discussion. The aim is to present the result of the analysis as a narrative based on participants' words.

5.7 Categories and Concepts

Four main categories were identified during the open and axial coding processes which reflect the interviewees' subjective experiences whilst working with their literature domains. These are:

- The research community
- Literature
- Influence
- Evolution of a discipline

The research community forms the central category around which the theory can be explained since it surrounds and pulls together all the other categories. Each of the categories will be discussed separately as they form the basis for the complete theory. However, before discussing these categories in detail it is important to demonstrate the ways in which these categories have evolved. As indicated in Section 5.4, the analysis level underwent an iterative process where the categorization of concepts was being constantly refined.

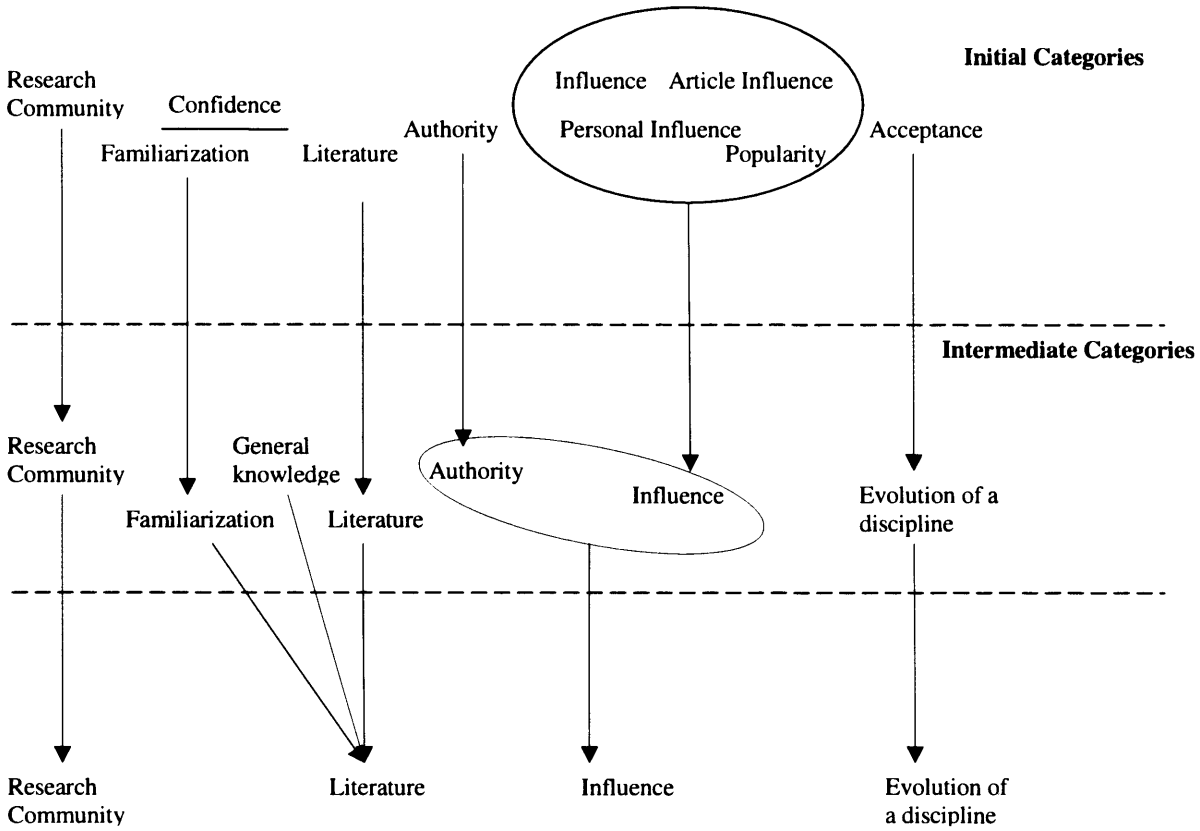


Figure 5.4 Category evolution

Figure 5.4 demonstrates that by giving an overall view of this evolutionary process. As seen in the figure, ten categories were generated at first; however after the iterative analysis process four categories were finally generated. This process included tasks such as: grouping, refining and elimination. For example:

- Authority, influence and popularity were all grouped into the influence category which will be explained in detail Section 5.7.3.
- Familiarization and knowledge gain became concepts that are part of the literature category

Throughout the following section, when discussing each of the categories there will be a section in each discussing the evolution of the concept by referring to Figure 5.4.

5.7.1 The research community

The research community represents the central category around which the sensemaking process begins.

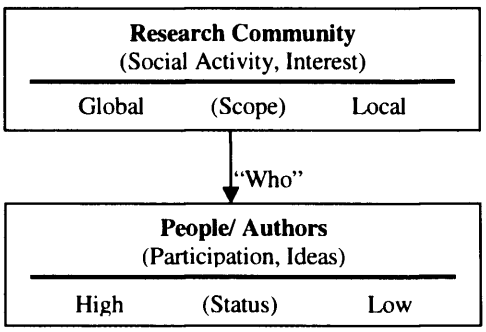


Figure 5.5 The research community category

From a higher level perspective, the community can be seen as reflecting a *social activity* or event where people with similar *interests* communicate to share ideas and knowledge (Figure 5.5). Following are a few examples of participants explaining what a research community means to them:

> *P1: "It is a place where you can **collaborate**...share ideas with other people".*
>
> *P2: "...a group of people having a **common interest**".*
>
> *P5: "...I think that **good communication** within the community is quite crucial to science".*
>
> *P8: "...I see is a kind of research community which will... yeah I'll evaluate their work they'll evaluate mine and we will **discuss ideas** um related to a particular subject area".*

A researcher's community varies along its dimensional scope from *global* to *local*. Global reflects the outside community to which the researcher belongs. Contact with members of such a community is done occasionally, when meeting in conferences, via e-mail or through telephone conversations. For example:

> *P3: "...there is a community that bases itself around a particular **conference** or a particular **set of conferences**".*

On the other hand, the local community represents the immediate community which surrounds the researcher on a daily basis, for example, members of his or her research department. For example:

> *P4: "...the head of **this mini research community**...will have an impact on where research is going to go".*

With the availability of communication technology people do not need to be in the same place or location, hence opening up communities. Therefore, one's research community is not location specific; instead it is specific to the interest which it incorporates. Such interest can be shared by members from various locations, as P8 explains:

> *"**No it is not location specific** because you know it is not in any sense proximity so there is people that I am in regular contact with through phone or e-mail and we exchange ideas and they are not even in the same continent".*

The community is made out of members who form the main entity around which the community exists. Therefore, as seen in Figure 5.5, *people* represent the community's direct subcategory. It is these members, the people, which *participate* in expanding the general body of knowledge, as expressed by P4:

> *"... you [member] are meant to be **contributing** to a body of knowledge".*

Such is achieved through the *ideas* they possess which is reflected through their work, in other words their publications. Researchers have to be *productive* in order to be members of their community. Such is reflected by the work and ideas they represent and communicate to the world. For example:

> *P7: "...everything really, **publishing** ...**presenting** at meetings, **contacting people** maybe via e-mail or speaking to them on the telephone...I suppose that can make you part of the community".*

Members of a community vary in *status* or *ranking*, where certain members were referred to as being *the core members of the community* as expressed by P3:

> *"...there'll be a **core body of people** who are aligned with particular kinds of ideas".*

This variance is reflected by the influence they reflect over their communities, as seen in the following quotation which resulted from the researcher being asked what was the role of the community:

> *P8: "...they [influential authors] can **direct research** in a certain way and you know those are people who will head a particular research community because they are well known...it is **status driven** because people not only want to know what the top people are doing they also want to know if they can collaborate with them".*

Influence will be covered in more detail in Section 5.7.3.

A note on the conceptual evolution of the community

The sense of community was a striking concept that emerged from the first interviews and continued to show throughout the rest of the interviews. As the data show that an essential step in the making sense of literature is to determine which community ones' research fits in.

5.7.2 Literature

Literature represents the concrete pieces of information from which knowledge is gained. It is through literature that knowledge is transferred and communities are formed. However, literature in this sense does not just represent the actual physical papers, but also the *ideas* which these papers reflect. These ideas are documented within publications, and are created from researchers' subjective views. Ideas are what researchers generate in the sensemaking process (Figure 5.6). Following are examples where participants were referring to the ideas that are generated out of the literature:

> *P4: "... I read a lot about what is going on and try and sort of like make sense of all those* ***ideas****".*

> *P6: "...I think I would go for* ***ideas****...what it means actually it is* ***not the paper but the ideas****".*

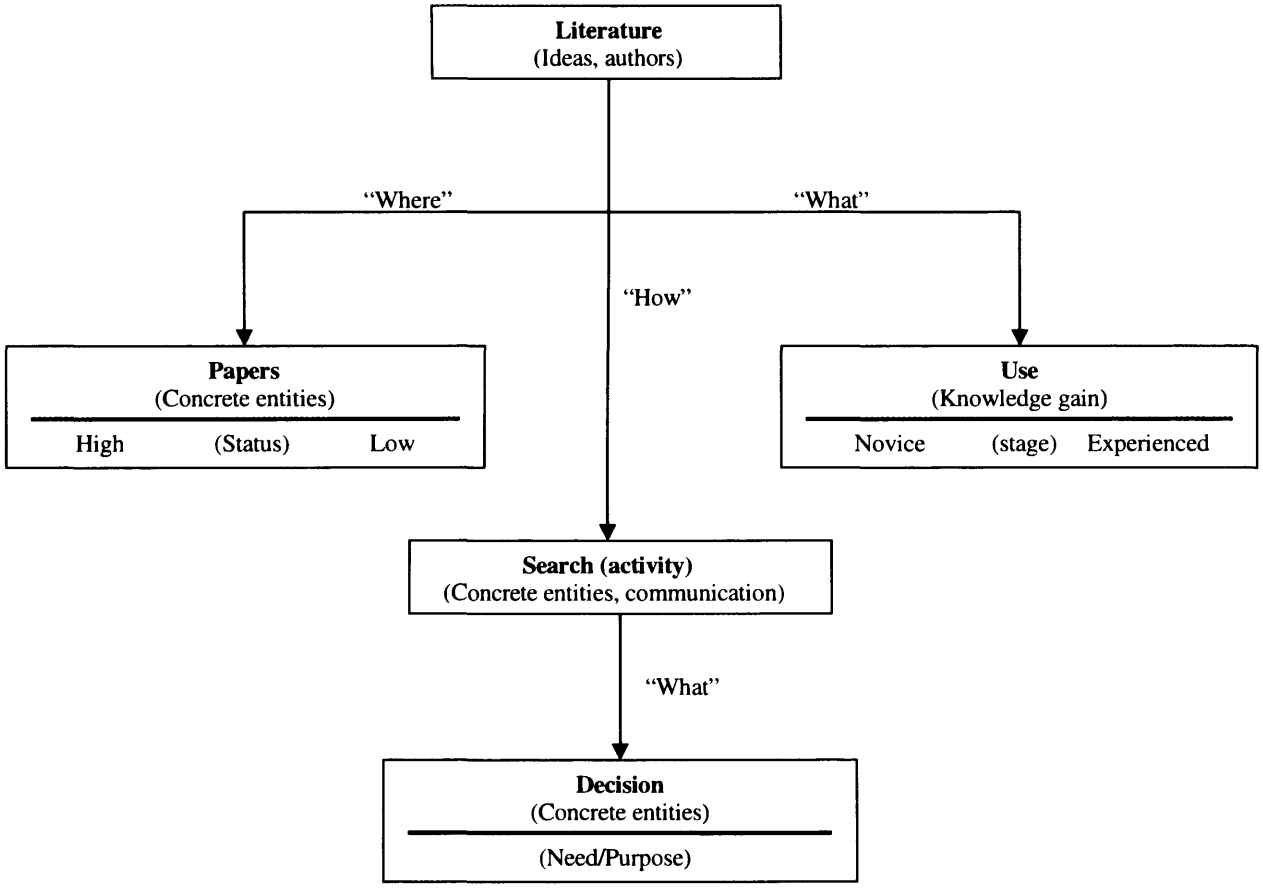


Figure 5.6 The literature category

Papers form a direct subcategory of the literature (Figure 5.6). They form the *concrete entities* from which knowledge of the academic literature domain is gained. These entities can be summarized as follows:

- Authors' names
- Topic: keywords, title
- Abstract
- Introduction
- Conclusion
- Publication year

In addition, a paper's *status* is also of interest; this is mostly reflected by the status of their publication source for example, status of the journal, conference, etc. Authors are the ones responsible for producing publications, papers. However the distinction between author and paper was not made apparent by the researchers during the interviews unless they were explicitly asked, such reinforces the notion that the actual physical paper is not a primary interest in the literature domain sensemaking process. It is more the ideas that these papers represent, which they often associate with their authors. Following is a discussion of the relationship portrayed by the interviewees between authors and papers.

Author vs. paper

When one of the participants was asked how s/he viewed the relationship between authors and papers, the participant responded:

> *P2: "It is hard to separate that [articles] from authors, cause ultimately they **were written by authors**".*

After analyzing the data it was identified that the distinction between both is not evident, since participants tend to change the referent when referring to authors and/or papers. Following are some examples:

> *P2: "I **look at who** is out there doing that sort of work, I look at **those papers**"* – There seems to be some sort of an association between author "who" and paper, as if they were equivalent.
>
> *P4: "...that [paper] was really good for me because I'd been reading lots of things previously ... reading **that paper he** kind of hit a lot of nails on the head"* – A similar issue arises in this example, where the participant is talking about the paper and refers to it as "he".

In addition, participants seemed to associate people to the citing task rather than the paper itself, following are some examples:

*P1: "I also **look at people** who have cited the paper"* – the participant uses the word "look at people" and not "look at papers", where the actual action involves explicitly looking at the papers.

*P4: "...I would use his [influential author] papers as a way of kind of giving me **pointers to other people** whose **work** I might look at"* – The participant indicated that he/she would use papers to point him/her to other people, and not papers. More interestingly the participant referred to a paper as work, when saying "whose work" and not "whose papers" this reinforces the notion that it is the idea that is important rather than the actual paper.

It can also be generalized that during the interviews participants always seemed to remember the names of the authors that they were referring to in their examples. However, when talking about a particular paper they seemed to either refer to it as "the paper written by ..." or they referred to it by explaining the ideas that the paper presented. For example:

*P5: "...sometimes you normally put, well if you kind of **remember the names together with the research topic**".*

*P8: "...so people that I know that I end up reading some of their recent work so I'll remember by name, but if it is people that I don't know all that well I'll remember say either the **idea** or the particular experimental **technique** that was used rather than the actual name or the title of the article".*

Hence it can be concluded that it is more the ideas that the papers represent which are of interest to researchers as part of the sensemaking process rather than the actual papers. The actual papers' entities are used as the low level entities that researchers work with. The generated ideas represent the high-level knowledge and are associated with the *authors* who are ultimately responsible for them, making the *authors* an important property of the literature category.

Literature is used for various reasons at various stages of research, where the main goal is the *knowledge gain. Knowledge gain* in this context reflects the knowledge of the domain. The extent with which researchers work or use literature varies depending on their knowledge of the domain and experience. *Novice* researchers go through a stage of *familiarization*, where they need to get familiar with the domains to which they are part, for example:

*P1:"...**get a feel** what they are doing and how they are doing it".*

*P2:" ...**be familiar with** the literature and sort of identify a problem and work on it"*

During this familiarization stage researchers engage in various tasks in order to gain information of their literature domains. These tasks are explained next.

Knowledge of community members

Researchers at the familiarization stage start by identifying the members of the community that have similar interests. It is the work of some of these members, the influential ones that introduces novices to ideas and other members in the field, for example:

> *P3: "...I started to build a feel of **who was who** in that area".*
>
> *P8: "...it was a good place to start in kind of **tracking the development of the ideas** ... by **looking at the people** who are ...still are pursuing it [ideas]"*

Discovering the specific research interest and associated question

One major problem that faces novice researchers is trying to narrow down their interest, and identify a specific research topic or problem. Understanding their literature domains through interacting with literature assists in solving such a problem, for example.

> *P2: "... **be familiar** with the literature and sort of identify a problem and work on it".*
>
> *P5: "...to **find a topic** as well because at the beginning I started and I was not sure of what I want".*
>
> *P7: "I think that when you start out you are not really sure exactly what you need to focus on any particular time... so perhaps **search for things by one particular author** or a very kind of general idea and then focus in".*

Other than the literature domain knowledge gain, literature is used for various other reasons. Such reasons vary depending on the researchers' needs and experience. For novices, whether in their research career or in a new field, literature forms one of the main sources from which researchers get ideas, understand new concepts, and keep track of knowledge, as expressed by the following participants:

> *P2: "...look **on previous knowledge** and build on it"*
>
> *P5: "...I had to read the literature and see what has **been done already** and what is related".*

As researchers gain experience, the extent with which they use literature changes, and hence literature uses differ. In certain cases it drifts away from being one of the main sources of knowledge to being used for other reasons, for example a social duty as expressed by P3:

> *"...at one level it is an obligation...it is a **social duty**".*

Researchers actually search for literature either via digital means where they use *concrete entities*, or through *communication* with other people. When digitally searching for literature, people use different entities to try and locate pieces of literature; such entities are summarized as:

- Search for authors
- Follow citation Links
- Search for co-authors
- Search for keywords

An overview of each is given next.

Search for authors

Researchers use author names as a means to locate additional pieces of literature that may be of interest, as expressed by the following participants:

> *P6: "...I will go **from the author name** and then the keywords so that would be the subject area".*
>
> *P7: "...I did searches on the internet and things like that for papers that have been published by these people [influential]... **I search for the people initially**".*

Follow up citation links

One of the most common ways among researchers to finding pieces of literature is the following of citation links. By starting from a piece of literature which is of interest researchers can locate other pieces or authors through these citation links, for example:

> *P2: "you know what **references** do they [influential authors] use and you go and read those".*
>
> *P4: "...I would use his [influential author] papers as a way of kind of giving me **pointers to other people** whose work I might look at".*

Search for author's collaborators' work

It is not only the first author's work that is of interest, but also the second, third, etc authors that are of interest.

> *P1: "he [influential author] **co-authored** the paper with [another author] I went and read everything she had".*

*P5: "...if I have for example one influential author and he is always on the first place then I always need to **know the second and or third** author in order to identify the different papers".*

Search for general idea (topic/keyword)

More traditionally, researchers use general topic keywords to locate pieces of literature or authors that are of interest.

*P2: "I will Google the **topic**".*

*P5: "...I also do search on PubMed on **keywords** which I am interested in".*

*P7: "...I'll just know that there is an **idea** that I want to find out more about so I'll have to try different combinations of words until something comes up"*

In addition to electronically searching for literature, researchers rely on input from other researchers. They can point them to certain pieces of work or seminal authors that are associated with ideas of interest, as expressed by the following participants:

*P3: "When I started my **supervisor** would point me to certain things".*

*P6: "...I think it is through **other people as well**".*

When locating literature, or in this sense papers, the decision as to which paper or publication to read depends on one or some of the following:

- Topic, keyword and/or title
- Abstract, introduction and/or conclusion
- Author reputation
- Number of citation links
- Journal or conference status
- Year

An overview of each is given next.

Topic/keywords/title

As the primary means to decide whether the paper seems to be of interest, researchers look at the paper's title and keywords. Following a few examples, as expressed by the participants:

*P3: "I would look at the **title** and judge from that, but if that doesn't work then I will open the **abstract**".*

*P5: "Well I read the **titles**...so something where I can spot a **keyword** which is related".*

Abstract/introduction/conclusion

Some researchers read the abstract to determine their interest in the paper. If this is inconclusive, they tend to read the introduction and the conclusion. The following are quotations extracted from the data:

*P1: "I read the **abstract** and then I read the **conclusion**"*

*P6: "...I usually check the **abstract** ... I read the abstract, I read the **introduction** and the **conclusion**".*

Knowledge of the author (influence)

On the other hand, some researchers use their knowledge of the author and their work and a means to deciding the relevance of the paper, as these participants indicate:

*P3: "...It depends on how well I know the area, if I know the area really well already the first thing I look at are **the authors**. I am able to assess from who wrote it how useful it is likely to be for me...if it is an area I know slightly less well, then I would look at the title and judge from that..."*

*P4: "...if it is a new paper that I haven't come across before then I'd consider the **authors**"*

Citations and citing links

Citation links are also used as a deciding factor, where researchers use them to determine who cited the paper, and hence use their knowledge of the author as a deciding factor. In addition, other researchers use the total number of times the paper has been cited to determine the influence of the paper and hence use that as a deciding factor, as indicated by these participants:

*P1:" I also look at people who have **cited the paper**".*

*P2: "determine how often he [author] has **been cited**".*

Journal or conference status

Some researchers use their knowledge of the status of the journal or the conference of where the paper was published to decide whether or not a paper is worth reading, for example:

*P4: "If like the paper is published in like a crappy conference that anyone can get in then in terms of validity and respect and just how influential that is would be **lower than if it were in a journal**..."*

*P7: "I think it helps if something is from a **reputable journal**... I think that it helps when things are published in good journals but I don't think that it is everything I think it is more important that the paper is relevant".*

Year

Last but not least, in certain cases researchers tend to read recent papers rather than old ones. Hence, the publication year in this case is used as a deciding factor as expressed by P5:

*"...I often just read the **recent ones**, so if there is a paper from 1985 then I often don't read that...I normally look for the author and **year**"*

The effort which researchers apply when trying to find literature is related to their need at the time. Where in certain cases they need to find all papers that reflect a particular idea, and in other cases one paper is enough. Following are two quotations extracted from the data that express that clearly:

P3: "... [in a certain situation] you've gotta make sure that you have really covered all bases and have found everything that is out in the public domain... so I did a really really thorough search...whereas other things that are much less well defined as long as I feel that I have got a representative set of the literature that is what I care about, I am not worried that I have got absolutely every paper about the subject".

P8: "I would look more at the fine details than I would have done when I started out but that is because I didn't know how much more important they would be whereas now they are extremely relevant because they are the only thing that kind of separate one paper by someone from another".

A note on the conceptual evolution of literature

Looking back at Figure 5.4 it can be seen that there were categories that emerged at the early stages of the analysis such as familiarization, knowledge gain, and confidence that were no longer part of the final categories. As a result of the analysis it was apparent, as discussed earlier, that literature is not just about the concrete entities that it incorporates, but that it is in itself a process and an outcome. As part of this process users engage in activities such as searching and accordingly making decisions which is all part of the familiarization process, as a result familiarization is seen as what derives researchers' interaction with literature in general and hence cannot be considered as a category as it is a process. As an outcome of this interactive process, as seen in Figure (5.6), knowledge is gained. Hence, it can be seen that familiarization and knowledge gain become part of the literature category.

Last but not least, the notion of confidence. After analyzing the first interviews the notion of confidence came a long especially with the novice researchers, whereby they needed to be confident

in the value of the literature that they were finding, whereby they wanted to make sure, i.e. feel confident that the authors and the literature that they were finding were authoritative, in other words, influential. Confidence in the sense is related to the decision that they were making and the thoroughness of the search activity. It is also a feeling that differs from one person to the other. As a result, confidence as such was disregarded as a category, since it is out of the scope of this study. However, its literature related components, searching for papers, determining which one is suitable in addition to which parts of the literature are influential is very much part of the theory.

5.7.3 Influence

Influence is related to the ideas members are producing. Some of these ideas are more influential than others. Influence (Figure 5.7) is something that causes an *impact*. An *impact* is characterized by something that causes a change in the way people, members of the community, think and work. Whether such an impact is received with agreement or disagreement, it is still an indicator of influence. Following are a few examples of the ways in which participants characterized influence:

> *P1: "...one article or one publication that is a **push forward**".*
>
> *P2: "I would look at the number of citations no matter whether **I like his theory or not**".*
>
> *P8: "I think in that sense then yeah they **do direct** for better or for worst they do direct, **have an influence in where other people then take their research**".*

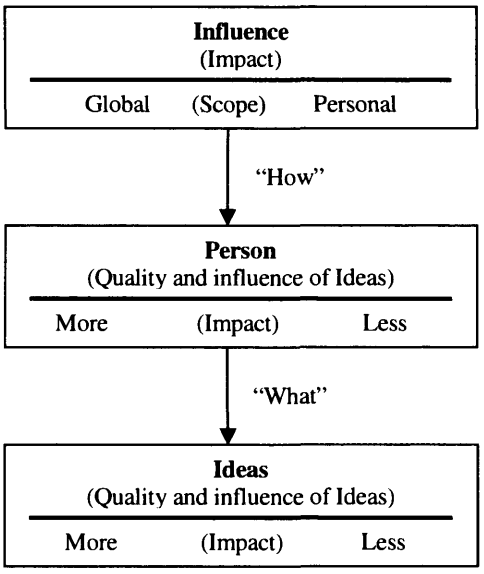


Figure 5.7 The influence category

Such an *impact* may cause for a change on a *global* or a *personal* level. Meaning that the changes that occur may be reflected on the domain in general, representing the *global* level. On the other

hand, changes may also occur on the *personal* level, where it occurs on a smaller scope affecting the actual researcher and his or her ideas and work and not the global community, for example:

> *P1: "...it [paper] got **me interested** first"* – the researcher gave this comment as she was asked to give an example of a paper that was really important to her.
>
> *P2: "...not many people are **doing what I am doing**...I guess that they [influential people] are influential in that sense".* – the researcher gave this comment when asked to give an example of an influential author and give the reason why this author is influential.
>
> *P3: "...there have been papers that have been influential ...actually changed the way **I have thought of my work**".* – the researcher gave this answer when asked to give an example of the paper that she thinks is important to her
>
> *P4: "I suppose when you say influential I consider it to be **influential to my own ideas**".* – the researcher gave this comment when asked whether there was an influential article in his research area.

It is people, in other words the members of the community, who are the ones responsible for causing such changes. Therefore, as represented in Figure 5.7, people form a direct subcategory of the influence category. The impact that a person causes in a community's knowledge in general, is related to the impact and *quality* his/her *ideas* have. The more impact the more influence and vice versa.

It is crucial to point out that it is impossible to put an explicit measure on the amount of impact or change caused by a person, since this characterization is very subjective. However, there are certain factors, such as the number of citings an author gets and the status of the publication, which assists in determining the extent of this characterization, as expressed by these participants:

> *P3: "I think **they [influential authors] are cited a lot**, but you get to hear about them for other reasons"* – the researcher answered this question when asked if she though that there was such a thing as an influential author.
>
> *P4: "...if it was influential to the wider research community, **citing is one way to measure that**...a more informal measure is just like the effect"* – the researcher gave this comment when asked whether there was an influential article in his research area.

However, determining whether a person is influential or not does not merely depend on the number of citations and quality of publications: it also incorporates other factors, for example the organizational status of a person as expressed by P8:

> *"...they can direct research in a certain way and you know those are people who will **head a particular research community** because they are well known"* – the researcher gave this comment when asked to talk about the research community in general.

The influence of such people is reflected through the influence of their ideas that are represented within their publications. Therefore, as reflected in Figure 5.7, ideas are represented as a subcategory of the people. This relationship is expressed quite clearly by these participants:

> *P4: "...an author is a collection of **influential articles**"* – the researcher gave this comment when asked to reflect on how he sees his literature.
>
> *P7: "...the more stuff that you **publish** that is **influential** or contributes something that is quite significant the more you will be regarded as kind of an influential author"* – the researcher gave this comment when asked whether she thought that the author of an influential article influential.

Contrary to the influential author, it is very rare to find a paper that is influential. In most cases it is the idea itself that is influential which may be presented through a group of papers, rather than a single paper. This is expressed clearly by these quotations:

> *P3: "...that is not just one paper, but **several papers** in line"* – the researcher gave this comment when she was asked whether she thought that there was such a thing as an influential paper.
>
> *P5: "...I know that he [influential author] specifically is answering one question and has published **10 articles on that**...it is more the work of **several articles** from one author rather than one article...It is not often that one article always comes up"* – the research gave this comment when she was asked to elaborate on the difference between an influential article and influential author.
>
> *P6: "...I think I would go for **ideas**...what it means actually it is **not the paper but the ideas**"* – the researcher gave this comment when she was asked whether publishing an influential makes its author influential.

Therefore, it can be concluded that the impact that is caused on the community is directly related to the ideas themselves which are the cause for such changes. Determining whether or not and idea or a person is influential can be subjective as influence can be sometimes be confused with other concepts such as popularity, as was revealed by the interviewees when asked to explicitly distinguish between influential and popular:

> *P6: "I think that **they** [influential authors] are just **popular**"*
>
> *P7: "...I think that people who are **influential are often popular**... I think that influence is related to how much they contribute to the field and whether they change things or add things...I think that it [number of citation] can reflect either [influential or popular] ...the **two things are quite close together**"*
>
> *P8: "...they [influential authors] have a manner about them that sometimes makes them difficult to approach"*

A note on the conceptual evolution of influence

Influence, as explained earlier can be a very subjective measure as it is depended on researchers' personal views and backgrounds. During the course of the study the users when talking about the ways in which they made their decisions about literature they generally referred to the number of citations a publication or an author had. When trying to investigate what the meaning of such a concept meant concepts such as: authority, influence, and popularity came about. Trying to investigate this further, as seen in the previous section the interviewees were explicitly asked to distinguish between influential and popular. As seen, in the examples given above this distinction is very subjective and difficult to break-up. As a result, influence, popularity and authority were all grouped together as influence. In addition, it is important to note that it is during the primary interviews that a distinction between author and paper was starting to be apparent as researchers were talking about the differences between the influence of a paper and an author. As a seen in Figure 5.4 there are two distinct categories influence of a person and influence of an article. Further investigation has lead to the discussion in Section 5.7.2 with regards to the distinction between author and article.

5.7.4 Evolution of a discipline

When participants were talking about their experiences interacting with literature some pointed to the fact that it assisted them in understanding the means with which their research disciplines have evolved. The evolution of a discipline is something that is related to a change in the status quo. It can be defined as the way in which a discipline progresses or evolves through time. It is normally caused by radical *changes* in influential people's *ideas* over a period of *time*; as seen in Figure 5.8 (below), evolution occurs when such ideas are met with general acceptance by members of the community.

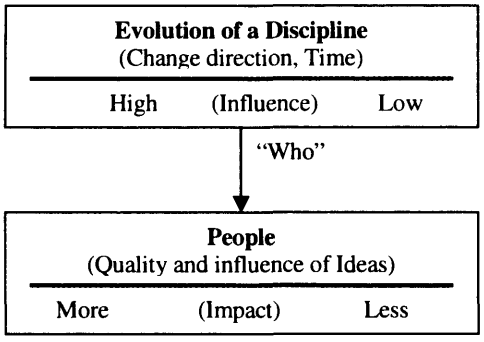


Figure 5.8 The evolution of a discipline category

Following are a few examples from which the evolution of a discipline concept was defined:

> *P3: "...there'll be a core body of people [influential] who are aligned with particular kinds of ideas but those ideas will become more or less widely accepted...they* ***evolve gradually with*** *time...it's one person [influential] that kind of hopped over and radically changed their views"*
>
> *P4: "...they [influential people] are in a position where they decide* ***where research is going****"*
>
> *P7: "...there is that thing of collaboration so that you work together and then perhaps people from* ***different disciplines can perhaps contribute to one another's work and it'll develop that way****"*

In addition to *changes*, *time* represents a major property of this category. It is these changes that happen to the community's work, ideas and interest over periods of time that cause a discipline to evolve, as expressed by the following participants:

> *P1: "... [HCI] evolved from... not necessarily* ***simultaneously*** *but right around the same time"*
>
> *P3: "...they [ideas]* ***evolve gradually with*** *time"*

Not all interviewees were interested in the concept of discipline evolutions, as expressed with the following quotations, which points to the subjectivity of the knowledge that can be gained from researchers' interaction with literature. The following examples are quotations that resulted from asking researcher whether they had an idea of how their disciplines have evolved.

> *P4:"...it is a bit* ***beyond my scope****"*
>
> *P7: "...I suppose it is about* ***what people find interesting*** *and you know decide to invest their time in".*

A note on the conceptual evolution of evolution of a discipline

At the first stage of the analysis the concept of the evolution of a discipline was not really apparent. Researchers were talking about the notion of acceptance, more specifically wide acceptance and personal acceptance of an idea. Wide acceptance can be seen from the perspective that the community in general is accepting a specific idea and this can be seen in the manner in which the community itself has evolved. Whereas personal acceptance, is related to the person accepting a specific idea meaning that a specific idea had an influence on that person. Hence, form here it can be seen that the idea of wide acceptability has been reframed into a category which is called evolution of a discipline, and the personal acceptance is part of the influence category.

5.8 The Full Picture

By iteratively analyzing the above categories and their associated subcategories, it has been noticed that they interrelate through their properties and dimensions. This interrelation, as seen in Figure 5.9 below; the *community* acts as the central category from which everything else emerges. Looking closer at the diagram, it is actually the *people*, who are the members of the community, and their associated *ideas* that tie up the different branches together. Knowing who the members are, and their associated research ideas, and work, represent the main steps in understanding one's literature domain (Section 5.5).

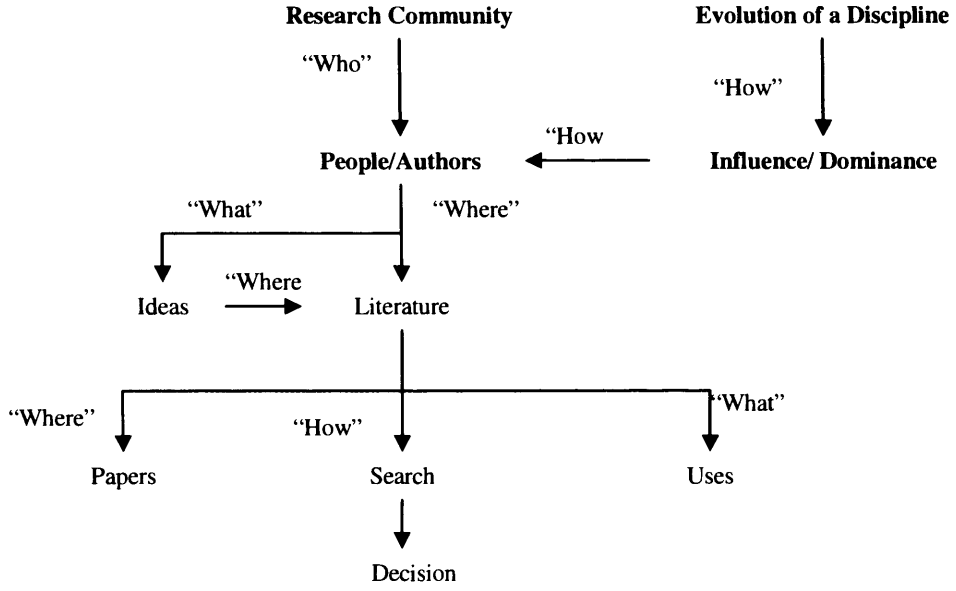


Figure 5.9 The full picture of the academic literature sensemaking process

It is in the *literature*, more precisely *papers*, where the knowledge of the literature domain resides. By searching for literature either using its concrete entities or communicating with others, much of this knowledge is gained. Therefore, *literature* is the means one uses to gaining such an understanding. In addition to this direct concrete knowledge of who the members of the community are, and their associated ideas, additional information is perceived. Such information is related to *dominance and influence* of people within the community and their associated ideas. This perception assists researchers in better understanding their domains, since it aids them in locating other seminal members and ideas. Knowledge of the dominant members and their associated ideas reflects how these ideas affect the community as a whole, leading to gaining an understanding of high-level concepts such as the *evolution of the discipline*.

5.9 Interpretation

By interpreting these interrelated categories further, Figure 5.10 is generated.

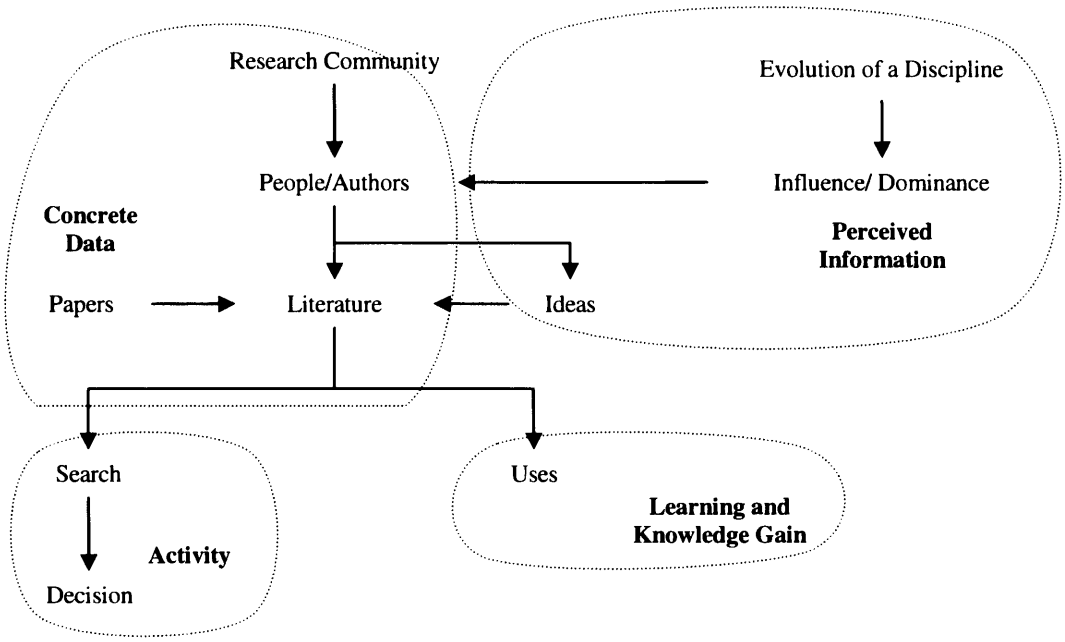


Figure 5.10 Grouping the literature domain understanding process

As a result, the categories can be broken down into four different parts which relate to the process in which the literature understanding occurs; these parts are:

- The concrete data
- The activity
- The perceived information
- The knowledge gain

Following is an overview of each.

Concrete data

As seen in Figure 5.10, the concrete data reflects the pure factual data from which the researchers make sense of their literature domains. It represents the entities they work with throughout the understanding and knowledge gain process. It includes both the *community* and the *literature* categories and their associated subcategories.

From the properties of these categories and their associated subcategories, the following concrete entities have been identified:

- Community's interest
- Community's scope
- Members of the community and their associated ideas
- Member status
- Paper entities
- Authors' names
- Topic
- Keywords
- Title
- Abstract
- Introduction
- Conclusion
- Publication year
- Journal
- Paper status
- Journal status
- Citation links between papers
- Citation links between people
- Collaboration links between people

These represent the main entities researchers use within the sensemaking, understanding and decision making processes.

Activity

Throughout the sensemaking and familiarization processes the main analysis revealed that there is always an activity with which researchers are involved, such as searching for literature and making decisions as to which piece of literature is relevant. These activities occur as researchers interact with the concrete literature entities as seen in Figure 5.9.

Perceived information

As a result of interacting with the concrete data, additional information may be deduced, such as forming subjective views, determining influence, and forming views of a discipline's evolution, all are depicted as part of the ideas that researchers generate as a result of this interactive process. Such perception is derived from the concrete data in addition to an individual's point of view and interpretation, hence forming a subjective perception and not facts. It is not a concrete measure, meaning that there are no correct or wrong answers. It varies from one researcher's point of view to the next, where in certain cases researchers can perceive information *other* than influence and evolution. Following are some examples of information perceived from the authors of a paper:

P5: "Um, yeah and you can kind of infer from that [authors of a paper] who was working with whom for a long time, or not such a long time and then you kind of recognize that some people are working on the same topic but never together on one paper so you can draw some inferences about how they are getting on". – Personal inferences.

P5: "...so yeah the second and third authors, yeah you can sometimes see a development as well, so the earlier papers then they are sometimes on the paper and then after a while they are more often at the beginning and you can kind of find out, ok there he was PhD student and then he moved on and now he is a professor himself, so you can kind of see that on the papers already". – Authors' status within the community.

Learning and knowledge gain

The learning and knowledge gain of the domain is the major goal behind interacting with one's literature domain. When interacting with the concrete data certain amounts of information is perceived, and therefore knowledge about the domain is gained. The learning of one's literature domain is a slow, and in some cases, unintentional process that happens gradually with time. In addition to it being slow and gradual, it is important to emphasize that it is not only through searching and working with the literature domain's concrete entities that people learn, but it is also through communicating with members of the community as indicated earlier.

Information of the literature domain is being gained all the time throughout a researcher's career. This processes of learning starts as soon as the researcher's career begins, as emphasized by the interviewees. Such a stage is known as the *familiarization* stage as indicated earlier (Section 5.6.2). However, the way that researchers use literature changes with time, where it moves away from working with literature to communication with people.

*P3: "...more recently it has been much more based on **meeting people** and **making connections with people** as people not the documents as such".*

*P5: "...by **talking to other people** basically, by going to scientific talks".*

All such information, whether related to authors, dominance, evolution, etc is knowledge that is continuously being gained throughout the researcher's career. This gain occurs gradually with time and in most cases is unintentional.

*P1: "...so it was a **slow process** of learning where to look for these things, reading them and just getting interested"*

*P6: "...**no it just happened** [unintentional] ...This is very dangerous because I may miss out"*

P7: "I didn't set out to do that deliberately"

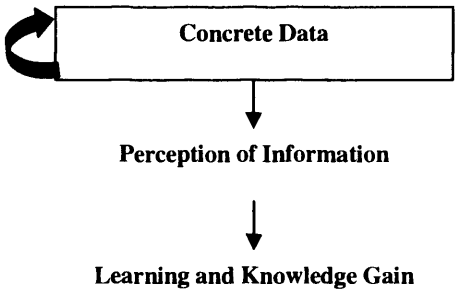


Figure 5.11 The literature domain understanding process

From this interpretation, it can be concluded that the understanding and sensemaking of one's literature domain starts with the concrete data (Figure 5.11). By interacting with the data through a number of activities, information is perceived and knowledge of the domain is gained. This knowledge may differ from one researcher to another, depending on their needs and experience at the time. Therefore, it is safe to say that working with the literature domain is an experience that differs from one person to another. It forms a major part in any researcher's career.

5.10 Generalisability

Before concluding this chapter it is important to discuss the generalisability of this academic literature theory beyond the sample populations that participated in its generation. All participants are researchers in the domains of HCI and Psychology, where HCI is a multidisciplinary field which emerged from both Computer Science and Psychology. Thus, the participants in this study have similar academic backgrounds, making it possible to identify common patterns in the manner in which they reason and make sense of their domains. Hence, the applicability of this theory to other domains is dependent on the characteristics of the domain and the culture in which its researchers work with and make sense of their literature. It is likely that researchers in arts and history work with literature differently from researchers in scientific fields such as Computer Science or Engineering. This can be seen in Dalton and Charnigo (2004), where they identified that even though historians are starting to use and appreciate electronic resources, yet e-journals are very rarely used. Humanities research is still very much dominated with prints (Rimmer et al, 2008), as the physical library is still very much the humanists' laboratory.

The theory generated in this study resulted from a grounded theory analysis, whereby it is grounded within the data. As a result, it is generalized across the participants and researchers who perform research in similar ways and rely on similar types of resources. In addition, it can be argued that the theory discussed in this chapter is likely to be generalized across scientific

domains where researchers need to make sense of massive amount of electronic information as part of their research in order to determine the evolution and history of a specific idea. However, this cannot be claimed with certainty as the theory will need to be tested across various scientific domains before such a claim can be made.

5.11 Conclusion

This study assisted in generating a better understanding of how researchers of various levels of experience made sense of their literature domains through the generation of a descriptive theory that explained researchers' literature domain sensemaking activities. The study made evident that even though the literature domain is a concise domain, its interrelationships and dependencies are complicated and therefore need careful consideration, especially when it comes to building a visualization tool. In order to visually represent knowledge, subjectivity is crucial. Users must be able to incorporate their individualities into the visualization experience. This study resulted in the generation of requirements which will be used as the basis around which the ALD InfoVis tool will be built as explained in the next chapter.

6. Design of the ALD InfoVis Tool

6.1 Introduction

As a result of the qualitative analysis conducted in the previous chapter a descriptive theory of the means with which researchers make sense of their literature domains was generated. This theory is used as the basis for generating the design requirements of the Academic Literature Domain (ALD) InfoVis tool. This chapter describes in detail the methodical approach taken in order to translate the theory into a design. As a result of this, a prototype was implemented. The design of this prototype is also explained in detail in this chapter. The developed prototype differed greatly from literature InfoVis tools described in Chapter 4. It differed from KDViz based on the fact that it targets a variety of users with diverse needs and goals. It differed from IR visualization tools since the ALD InfoVis tool's design is based on researchers' conceptualizations of the academic literature domain.

6.2 From Theory to Design

The descriptive theory generated in Chapter 5 revealed the strategies that researchers adopt in addition to the entities that they interact with in order to make sense of the academic literature. As a result, it can safely be said that the study was successful in achieving its aims and objectives. At this point, these findings need to be translated into an InfoVis design. Based on the motivation of this research, the design strategy adopted takes into account the design of the externalization embedded within an interface, whereby both users' domain related sensemaking activities, which are related to the domain, and the interface related manipulative activities, are taken into account.

The challenge faced here is mainly related to the design of the externalization due to the subjectivity of the domain related conceptualization, as discussed in the previous chapter. As a result, the design strategy adopted by this research will emerge from translating the descriptive theory into a design rationale. The design rationale reflects the design of the externalization in addition to users' interaction scenarios.

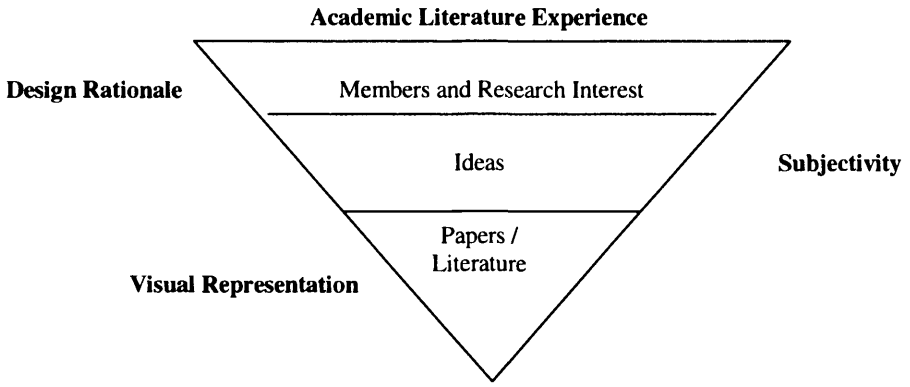


Figure 6.1 From theory to design: Designing the academic literature experience

By looking at the academic literature model created in Chapter 5 and presented in Figure 6.1 the members of the community, which are the authors, are at the starting point of the sensemaking activity. Inspired from this, the design vision is for the community, authors, to reflect the starting point of users' interaction with the tool, in addition to guiding users' interaction scenario. Hence, the strategies that researchers adopt in order to interact with the community are used to influence the design rationale of the tool. Figure 6.1 reflects the fact that papers, publications, represent the low-level entities that researchers adopt in order to interact with the data. As a result, publication data is used as the source of the low-level visual encoding of the ALD InfoVis externalization design.

Last, but not least is the notion of *ideas*, as reflected in Figure 6.1. Ideas, as explained in Chapter 5, are subjective, which means that they may not exist as part of the concrete literature data. For example, the same papers might be read by two researchers each with a different interest in mind, hence different ideas would be generated. This suggests two design implications: the first is related to the generation process of these ideas, and the second is related to the representation of these ideas as part of the visual externalization. First, the generation process of these ideas is related to users' interaction with the tool, as a whole. It is this generation process that is believed to be at the heart of users' InfoVis interactive experiences. Second, is the representation of these ideas which are quite subjective; this hints towards the notion of personalization of the externalization, whereby users are given the opportunity of overlaying their views onto the visual representation of the data. The rest of the chapter presents in detail the design decisions that were taken in order to translate this design vision into a functioning prototype.

However, before starting to explain this in detail it is important to point to the categories and their associated properties that were included as part of the design and the ones that were not. Due to the time constraints and the man power involved in this research some category properties were not

included as part of the design. As explained in the previous chapter four categories were generated: research community, literature, influence, and evaluation of a discipline, each have various properties and varies across the dimensionality scope. Following is an overview of the each of the categories, explicitly indicating which properties will be considered in the design and which will not.

6.2.1 Research Community

Research community forms primary source of the literature domain sensemaking process, as it incorporates the members of the community who are the producers of knowledge. The design will take into consideration the community members and their associated publications. Only the global community will be taken into account and not the local community. The design will not include the sense of self, i.e. representing the user as part of the community, as this is out of the scope of this research.

6.2.2 Literature

Literature in addition to it including the concrete data entities such as: title, author, abstract, etc, literature is all about the ideas that are communicated and reflected in it. Most of the concrete entities will be included in the design except for: source status, as this sort of information was not available in the dataset used (Section 6.5), and generating this information is out of the scope of this research. In addition to the concrete entities, the notion of idea will not be explicitly addressed by the design of the tool as this will require the design of an environment that will allow for users to add their generated ideas onto the dataset and this is out of the scope of the tool needed by this research. Hence, as explained in Figure 6.1 ideas that researchers generate will be looked at as part of the interaction, whereby the subjectivity of the experience will be addressed in a minor fashion as will be explained in Section 6.5.5.

6.2.3 Influence

Influence, as explained in the previous chapter is related to the impact that ones' ideas has, either globally, hence affecting the community as a whole, or locally, hence affecting the individual researcher. As with the community, the design of the tool will consider the global influence and not the local. Influence, can be measured using the number of citations a piece of work gets. In addition to this explicit measure, influence is also based on the subjective considerations, as explained in the

previous chapter. The design of the tool will only consider the explicit measure and not the subjective, due to the scope of the research.

6.2.4 Evolution of a discipline

Evolution of a discipline, based on the analysis conducted in the previous chapter is based on the influential ideas and the associated general acceptance by the community. Due to the subjectivity of the variable involved in such a category, the explicit representation of this category will be excluded from the design of the tool, as it is out of scope.

6.3 Externalization Design

The externalization is what users will see. It is made out of the concrete data entities and their associated relationships (Ware, 2004). The concrete data entities are overlaid with the visual encodings, whereas the relationships are used to structure the layout of the entities (Bertin, 1983). As a result of the requirement study conducted in Chapter 5 the set of concrete entities and associated relationships were identified and are listed.

Concrete entities

- Author
  - Name
  - Number of publications
- Publication
  - topic/keywords/title
  - details: abstract/introduction/conclusion
  - year
  - Source
  - Interest
  - Number of citations a paper gets
  - Reference (Complete citation String)

Relationships

- Collaboration between authors
- Citation (cites/cited by)
  - Between publications
  - Between authors
  - Between publication and authors (vice versa)
- Publication between authors and paper (Publish/published by)

The requirements study (Chapter 5) referred to the concept of *ideas*. Ideas may not be part of the concrete data as they may not be part of the dataset, or some of the expressed relationships. For example, users when interacting with a specific publication may generate ideas about a particular

publication which are related to the general topic of the publication, which is referred to here as interest. For example, this publication talks about interface design. This idea is clearly part of the concrete data, however another user may generate ideas in relation to the research methods that are applied by this publication, or infer certain ideas in relation to the fact that publications that have an interest in user interface design are closely related to publications that talk about representation techniques whereby they apply user interface design methods. Such inferences or knowledge are not part of the concrete data, as a result ideas are expressed as being subjective and are generated as the user interacts with the visual entities and such as authors or publications. As a result, this concept is discussed as part of the interaction design.

6.3.1 Concrete entities and the visual encoding

There are many propositions as how to encode information visually. The visual encoding process adopted by this research is based on the retinal properties. Bertin (1983) points to graphical properties known as 'retinal properties' since the human eye's retina are quite sensitive to them. He defines six different properties: size, value, texture, color, orientation and shape, where value may reflect a decrease in contrast such as shading, since the value decreases from black to white.

	Spatial	Object
Extent	(Position) —I—I—I Size ● ● ●	Greyscale ■ ■ □
Differential	Orientation — / I \	Color ■ ■ ■ Texture ■ ▨ ▩ Shape ■ ● ◆

Table 6.1 Retinal Properties (Card et al, 1999) (Data based on Bertin (1983))

In Table 6.1 the retinal properties are cross-separated according to whether their property is good for expressing the extent of a scale, i.e. has a natural zero point or whether its principal use is for differentiating between marks. This is reflected through either the spatial properties, e.g. size, orientation, or through the object's properties i.e. shape, color, etc. Some retinal properties are more effective than others for encoding the specific types of data (Card et al., 1999) where the basic data types are nominal, ordinal and quantitative:

- Nominal (N): reflects an unordered set such as fruits <apple, banana, orange>

- Ordinal (O): reflects an ordered set where it is possible to say that a certain item comes before or after another, e.g. when asking people to order fruits in order of preference we are asking them to create an ordered set
- Quantitative (Q): reflects a numeric range such as travel time in minutes

	Spatial	Q	O	N	Object	Q	O	N
Extent	(Position)	Good	Good	Good	Greyscale	Marginally effective	Good	Poor
	Size	Good	Good	Good				
Differential	Orientation	Marginally effective	Marginally effective	Good	Color	Marginally effective	Marginally effective	Good
					Texture	Marginally effective	Marginally effective	Good
					Shape	Poor	Poor	Good

Table 6.2 Relative effectiveness of different retinal properties (Card et al, 1999) (Data based on MacEachren 1995, (Figure 6.3))

Table 6.2 gives a detailed overview on which graphical property can be used to best encode data of the above listed types. For example, it can be identified that 'size' is a good visual cue for representing extent. A contrasting example would be that, when it comes to differentiating between quantitative data 'shape' is a very poor visual cue. This table is used to determine the visual cues that will be associated with the concrete data entities listed above.

Concrete Entities	Data Type	Object/Spatial Properties	Graphical Properties
Authors/Members			
Number of publications	Quantitative	Spatial Extent	Size
Publication			
Interest	Nominal	Object Differential	Color
Number of citation	Ordinal	Spatial Extent	Position
Source	Nominal	Object Differential	Shape
Publication Year	Ordinal	Spatial Extent	Position

Table 6.3 Variable types and their associated visual structure

Following the same process, the concrete data entities have been categorized according to their type and assigned a graphical encoding. Table 6.3 shows this in detail. Author details are discussed in the next section as part of the externalization layout.

Based on Table 6.3 publications can be displayed in a scatter-plot layout, where the x-axis represents the year of publication and the y-axis represents the number of citations (Figure 6.2) due to the ordinal nature of these properties. Size could have also been a good graphical property to differentiate between the extents of ordinal object. Hence, it could be argued that size of publication could have been used to represent the number of citation that a paper gets. However, the decision was to use the x-y axis layout.

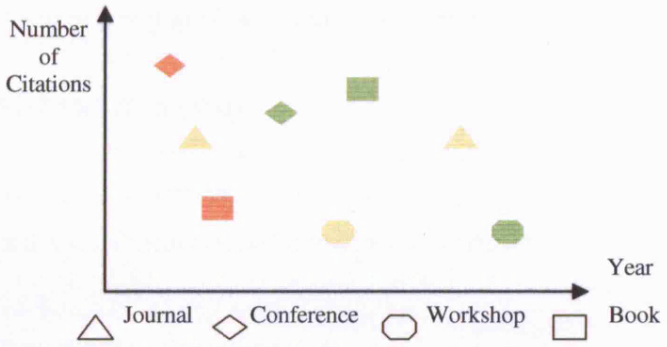


Figure 6.2 Article view

As seen from Table 6.3 size is not used as a visual cue since the publications are at the lowest level of the sensemaking hierarchy (Chapter 5). The color of each paper reflects the research interest of the paper and the source of the paper is reflected by its shape (Figure 6.2). The interest of a paper indicates the general topic line in which this paper was published, for example all green papers are papers that talk about interface design, whereas all yellow papers are papers that talk about information retrieval. From here it can be seen that both interest and source are nominal data types, and according to Table (6.2) color and shape are good graphical properties. Shape was explicitly chosen to represent the source of the publication due to the fact that as Engelhardt (2002) indicated that a graphic object is often equated with its shape, as a result shape was used to represent the source of the publications, as the source of the publications such as: book, journal, or conference is regarded as a major criterion that researchers use in order to distinguish between publications.

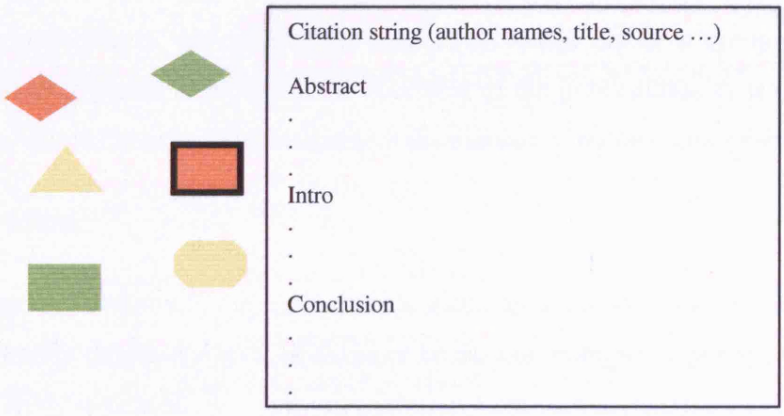


Figure 6.3 Additional paper information popup view

The additional publication details such as: abstract, intro, etc, will not be part of the visual representation as it has been established from the qualitative requirements gathering study that they

reside at the low details level of users' sensemaking activities. Hence they will be represented upon users' request in the form of a popup view as seen in Figure 6.3.

6.3.2 Externallzation layout

The externalization layout is dependent on the relationship that needs to be portrayed. There are three types of relationships: publication, collaboration, and citation.

Publication

The qualitative analysis (Chapter 5) revealed that the authors, in other words the members of the community, are at the center of all domain sensemaking activities. This is due to the fact that they are the producers of knowledge. Ultimately, papers are written by them and hence they cannot be separated as depicted in the following quotation taken from the requirements' study:

P2:"It is hard to separate that [articles] from authors, 'cause ultimately they were written by authors".

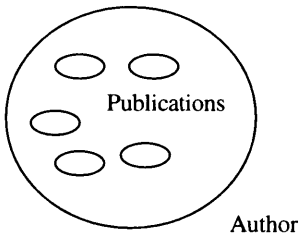


Figure 6.4 Author-paper relationship

From the interviewees' perspective the authors are made out of a group of papers/publications. Hence authors are used to represent the overview of the publications as seen in Figure 6.4. This is the reason behind choosing size to represent the number of publications (Table 6.3).

Collaboration

As discussed in Chapter 5, the community is made up of authors that collaborate with one another. It is not merely dependent on a first author basis. For example, a participant in the requirements gathering study indicated:

P5: "I always need to know the second and or third author"

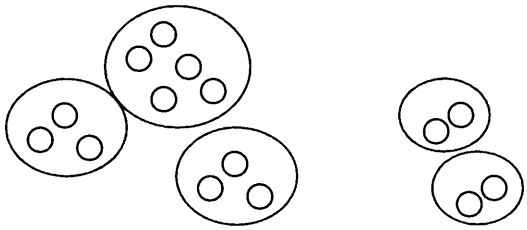


Figure 6.5 Authors' collaboration view

Collaboration relationship can be used as a means to layout the author nodes. Looking at the authors' concrete entities there are no ordinal properties hence the layout is dependent on the relationship between these entities which is the collaboration relationship. Authors that have collaborated together can be grouped together in a cluster as seen in Figure 6.5. The requirements gathering study (Chapter 5) indicated that researchers are also interested in the citation relationship between authors; this relationship could have been used in order to portray the layout of the author. However, the collaboration relationship was chosen due to its ability to represent communities of authors that work on similar interests. Citation relationship is also useful to represent author and interest communities; however, it is dependent on the context of citation which is out of the scope of this research.

Citation

Chapter 5 has shown that users are interested in citation relationships. Citation is a directed relationship, whereby a paper 'cites' another paper or is 'cited by' a paper, as seen in Figure 6.6

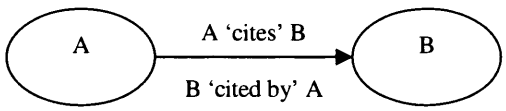


Figure 6.6 Citation: a two way relationship

From the analysis of the requirements study it was apparent that users are interested in citation relationships between publications and between authors. Citation relationship between publications is a direct relationship, i.e. a paper cites another paper. Citation relationship between authors is a generalized relationship, e.g. author A cites author B in three of his publications. The citation relationship will be displayed upon request, as it was apparent from the requirement study (Chapter 5) that researchers when working with citation information do so in a sequential manner in order to navigate from one paper to the other. Hence, identify the papers that cite a specific paper and not look at the domain via an overview of citations.

6.4 Interaction Design

From the qualitative study (Chapter 5) it was identified that the literature sensemaking process is a gradual one, where researchers normally start with a specific problem or question in mind. As a result, it is not necessary for the entire literature domain's data to be displayed at once on the screen. The researcher decides upon which areas of the literature domain is of interest and accordingly determines that sensemaking path. Hence the ALD InfoVis tool needs to have an exploratory style. Users must be able to communicate their requests to the system efficiently at any time during the course of the interaction. As a result, changes occur on the externalization in the form of visual feedback.

Interaction is related to the activities that the users perform in order to satisfy their goals. Hence, the manipulative activities are considered as instruments, based on the discussion presented in Chapter 3, where each instrument is looked at as being made out of a logical part and a physical part. The physical part is associated with the activity that the user conducts with the input device, whereas the logical part represents the visual aspect (e.g. the widget). Most manipulations are executed using the mouse, as an input device, except for the searching which is executed using the keyboard.

Activity Categorization	Manipulation activity (Instrument)	Physical	Logical	Outcome
Primary	Details	Click	Visual entity (Author)	View all publications associated with the author
		Drag	Visual entity (author/publication)	View citations of the selected entity
		Right-click	Pop-up menu	View the details of a publication (abstract, etc) Mark (Author, publication)
Secondary	Pan	Drag	Canvas/object of interest	Pan the canvas up and down
	Zoom	Scroll the mouse wheel	Canvas/ object of interest	Zoom into or out of the canvas
	Filter	Click	Checkboxes	Filters the authors to fit the filtering criteria
	Search	Type	Search box	Highlights the matching entities

Table 6.4 Instrumental breakdown of manipulative activities

Table 6.4 presents a breakdown of the manipulative activities indicating the physical activity associated with the action, the associated logical part, and the outcome of the action. After analyzing the requirements data it was apparent that the activities could be looked at from the perspective of two categories: the primary activities and the secondary activities. The primary activities represent the sensemaking activities that users engage with as part of their sensemaking

process whereby they interact with the 'details', i.e. the individual entities. From the context of the ALD InfoVis tool these are broken down into: revelation activities, and personalization activities.

- Revelation activates: are activities that users engage with in order to reveal specific relationships such as collaboration or citations, in addition to revealing details.
- Personalization activities: are activities that users engage with in order to personalize the visual representation, i.e. personalizing the entities (details).

Secondary activities are seen as supportive activities such as: search for an author or a keyword, and filter the data, etc. Table 6.4 shows that the secondary activities are reflected by: pan, zoom, filter and search instruments. For reasons discussed in Chapter 3 the design of the manipulative activities is based on the instrumental interaction properties (Beaudouin-Lafon, 2000): degree of indirection, degree of integration and degree of compatibility (Chapter 3).

6.4.1 Degree of indirection

As explained in Chapter 3, the degree of indirection is a 2D measure which incorporates spatial and temporal offsets. The spatial offset is defined as the distance between the logical part of the instrument (e.g. widget) and the object it appears on, the object of interest. Temporal offset is defined as the difference in time between the physical action on the instrument and response on the object of interest.

Due to the fact that the primary activities will be constantly used by the users as part of their sensemaking activities, hence all primary activities were designed with a small spatial offset since no widgets were used. Hence, the object of interest represents the logical part of the instrument (Table 6.4). For example, merely by clicking on an author her/his publications are revealed, hence the user will not need to click on a button in order to see the publications. The reason for doing that is to increase the directness of these activities, and as a result reduce the cognitive load associated with them. Whereas for the secondary activities, search and filter have a higher spatial offset as these activities are executed through the use of on screen widgets. This is due to the fact that in most cases it would be impossible to execute these activities by omitting the on-screen widget, for example, in order to search then a search text box is needed, and in order to filter then filtering widgets are needed or some sort of supporting tool is needed in order to create the queries. For the pan and the zoom activities the spatial offset is low as the mouse controls are used to directly execute these commands, where panning is done by clicking and dragging the background canvas and zooming is executed through the mouse wheel. Both the primary and secondary activities were

designed to have very small temporal offsets: as soon as the user conducts a physical action immediate feedback would appear. This was true except for the publication details as the user has to right-click on the publication to get a pop-up menu from which to choose a 'show details' options.

6.4.2 Degree of integration

Degree of integration measures the ratio between the number of degrees of freedom (DOF) provided by the logical part of the instrument to the number of DOF demonstrated by the physical part of the instrument. The only input device used in order to manipulate the externalization of the data was the mouse, its associated buttons, and wheel. The physical actions that are allowed by the tool are clicking, dragging, and zooming. For the clicking and the dragging, there is always a logical instrument associated with the action, such as a button or a checkbox which will have a DOF of 1. When user clicks on them the mouse button is used, which has a DOF of 1. This results in a degree of integration of 1 for the clicking action. Similarly for the dragging action, the users will drag the visual entities which mean that their DOF is 2 using the mouse which has a DOF of 2; hence the degree of integration of this action is 1.

The panning and the zooming actions will not have visible logical instrument except for the main view itself. Panning is done by dragging the window, meaning that it has a degree of integration of 1, whereas the zooming is done by scrolling the mouse wheel. The scrolling action and the mouse wheel both have a DOF of 1 hence the degree of integration of the zooming action is 1. From here it can be seen that all manipulative activities will have a degree of integration of 1.

6.4.3 Degree of compatibility

Degree of compatibility measures the similarity between the physical actions of the users on the instrument and the response of the object. This is applicable for the dragging and the zooming actions. When it comes to the dragging action, there is great compatibility between the users' physical action on the mouse and the response on the object, as the object follows the movement of the mouse. The problem however arises with the zooming action, where it is executed using the mouse wheel. There is an incompatibility between these two actions as when the user scrolls in (up) the display zooms out, and when the user scrolls out (down) the display zooms in. This is the zooming direction that was allowed by the InfoVis toolkit that was used to implement the ALD InfoVis tool. Due to time constraints no effort was put in to switching the actions.

6.5 The Implemented System

The ALD InfoVis prototype was based upon the design rationale discussed (Section 6.1). The visualized data was the dataset provided by Ke et al (2004) of the InfoVis'04 contest, and was provided in the form of MS Access database. This database was created from the original contest XML file which included the complete dataset of 8 years for all InfoVis conference papers and references from 1995 (Fekete, Grinstein, & Plaisant, 2004). The dataset includes publication title, authors, keywords, abstract, references, and links to original papers available in the ACM Digital Library.

The ALD InfoVis prototype used a new database that was created from the original one (Ke et al., 2004) by importing essential tables and queries. New tables were created from the original ones to satisfy the design needs. Only the authors that published papers within the range of the years 1995-2002 are the ones visualized, as Ke et al (2004) database incorporated publications that were out of that range due to citation information. For example, a paper published in 1995 cites another that was published in 1990; some of the authors of these publications were not part of the dataset. Taking these entities into account would have added to the design considerations; due to time constraints, the decision was not to visualize them. Hence, in total 846 authors, 417 publications and 1970 citation links were visualized. A more sophisticated design can be thought of as part of the future work. The Prefuse visualization tool-kit (Heer, Card, & Landay, 2005) was used to develop the prototype; additional features were implemented using Java (JDK 1.5.0). The prototype runs on windows XP O.S.

6.5.1 System layout

In order to give the user the freedom to manipulate both the authors, publications and associated citation relationships, in addition to keeping the identified author-paper relationship, the interface was divided into 4 views as shown in Figure 6.7. Having a single view display is good for showing the entities of a category in addition to the relationships which exists between entities of that category. However when it comes to revealing relationships that exist between different categories' such as: authors and publications it would be difficult since users would have to switch back and forth between views. On the other hand, having the multiple view display would allow users to view the various interrelationships which exist between categories' entities, in addition to the relationships which exist within a category without having to switch back and forth between views. Hence, the decision was to have a multiple view display scheme rather than a single view display

scheme. It is important to note that the edges of each view are adjustable, i.e. the user can increase or decrease the size of a view simply by dragging its edges.

Figure 6.7 is a snap shot of the tool's interface. Area (A) represents the two views that are on the left of the vertical division. These areas include author information. Area (B) represents the information that is displayed to the right of the vertical division and includes publication information. Area (B) can be seen as the details area and area (A) as the overview area since publications are details of the authors as explained in Section (6.3.2). Area (C) represents information that is above the horizontal division and includes collaboration information as collaborations between authors on publications. Area (D) represents information that is below the horizontal division and represents citation information.

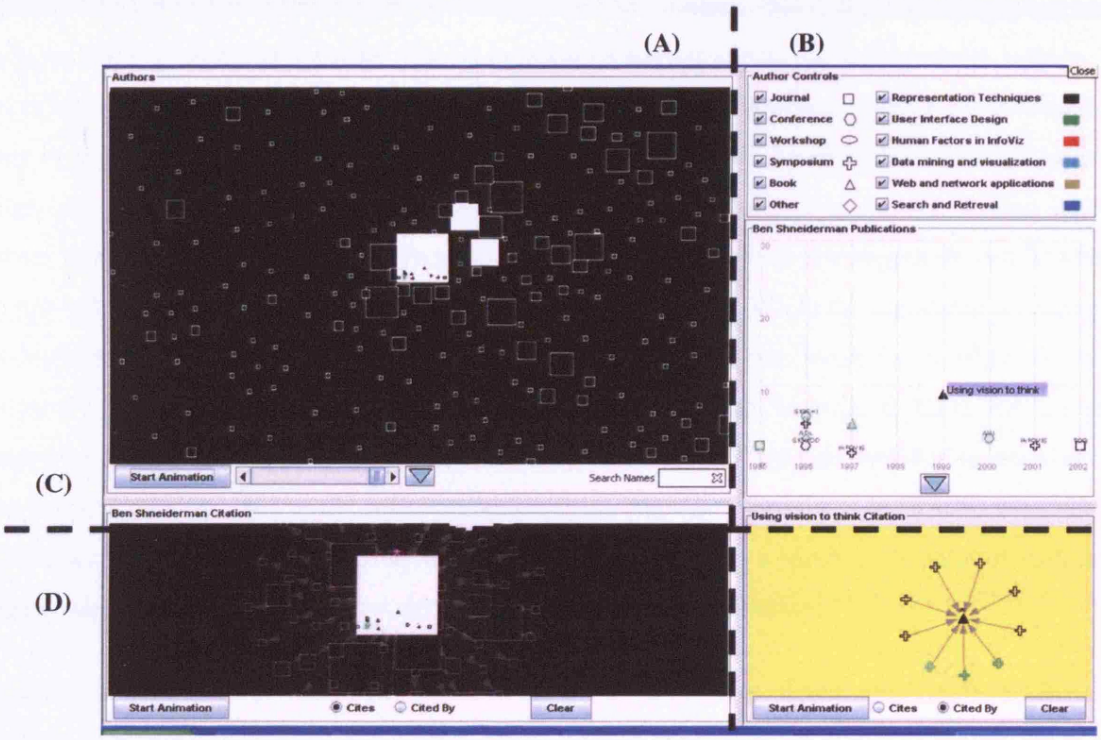


Figure 6.7 The ALD InfoVis tool layout

Breaking Areas A, B, C, and D further:

- AC: top left view is the author collaboration view.
- BC: right top view is the publication view.
- AD: lower left view is the author citation view.
- BD: lower right view is the publication citation view.

When the user selects an author, example "Shneiderman", as in Figure 6.7, all publications of that author are displayed in the publication's view. In order to explore the citation information either between authors or publications this has to be done explicitly either by dragging the publication into the publication citation view or the author into the author citation view. Each of these is discussed in detail by explaining the layout that is used and the associated controls. The personalization feature associated with the tool will also be discussed.

6.5.2 The author view

Based on the discussion presented in Section (6.3.2) the author view represents the main view that the users will interact with in order to make sense of the domain. In this view authors will be clustered based in the collaboration relationship. Hence, authors that collaborated together will be seen as being grouped in a cluster. Based on such clustering needs, the layout of the authors view takes the form of a force-directed layout graph. This layout, as will be explained in Section 5.7, is part of the layouts provided by the Prefuse toolkit, where nodes by default repel each other and edges act as springs bringing related nodes, in this case authors that have collaborated together, closer to each other. Based on the functionality provided by Prefuse this algorithm can be allowed to run infinitely or can be stopped after a certain amount of time. While the algorithm is running the nodes start to lay themselves out onto the display. The decision was made for the algorithm to run infinitely and not stop after the authors nodes have been laid out in order to allow for the author nodes to find their accurate layout in case they were moved by the user for reasons such as resolving occlusion. Due to the infinite nature of this algorithm there was a constant movement as the nodes will constantly be pulling and repelling each other. As a result, a 'Stop/Start Animation' button was added in order to allow the user to stop the constant jittering.

In addition to the 'Stop Animation' button located at the bottom of the author's view (Area AC) there is a visibility scrollbar and a search author textbox. The visibility scrollbar allows the users to fadeout the author nodes that are not of current interest to the user. In other words, all nodes that are not selected and not resulting from a search are faded out. In the example displayed in Figure 6.8 the user has searched for "Keim" which became visually distinguishable (red). The user then used the visibility scrollbar which was located at the bottom of the user view to fade out the other authors except for the ones of interest.

Figure 6.8 Search the author view

The user is also able to filter the author view; the filtering options are categorized into two categories: interest and type. Interest reflects the research interests of the authors' publications and type reflect the type of the authors' publications. Six research interests were identified. These are specific to the displayed dataset and they were not extracted computationally but were added manually to the database. Five of these interests were identified by Ke et al (2004) where they performed a burst analysis on the keywords, titles and abstract of the InfoVis 2004 contest dataset. These interests are:

- Representation techniques
- User Interface design
- Human Factors
- Data mining and visualizations
- Web and network application

A sixth interest was added:

- Search and retrieval.

This was done based on the fact that looking at the titles and keywords associated with the articles in the dataset, articles that dealt with data processing were not merely related to data mining applications, whereby data mining has a focus on databases and their associated applications, based on the 1998 ACM Computing Classification system. There were other articles that had a focus on digital libraries, clustering, query formation, retrieval and search processes. Based on the ACM

classification these are grouped under the search and retrieval classification, as a result a search and retrieval interest was added.

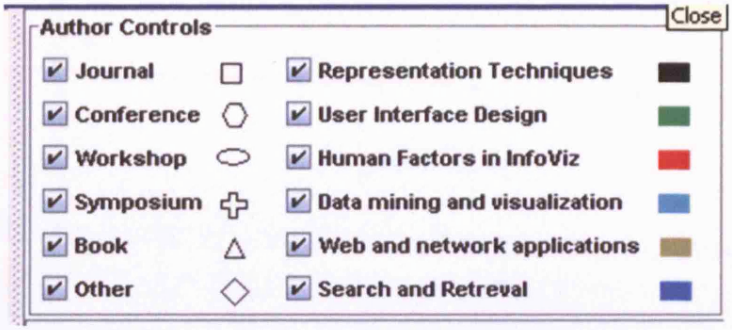


Figure 6.9.Author filtering controls

Figure 6.9 is a close up of the controls with which the user can filter the author view. If two checkboxes are ticked then this means that all nodes that fall into both these categories are displayed. For example, if journal and conference are ticked then this means that the authors that have journal and/or conference papers are displayed. Same applies for the research interest.

6.5.3 Publication view

Following from the example presented in Figure 6.7 where the user has selected "Shneiderman" hence all his publications (within the context of the dataset) were displayed in the publication view. The layout of the publication view (Figure 6.10) takes the form of a scatter-plot where the x-axis represents the year and the y-axis represents the number of times a publication was cited (Section 6.3.1). The colors of the publications reflect the research interest and the shape reflects the type. From here it can be seen that "Shneiderman" is mainly interested in user interface design and representation techniques.

As the user right-clicks on the publication a pop-up menu appears which would allow the user to select a 'view details' where the details of the publication (title, abstract, reference) are displayed in a pop-up window. In addition, as the user selects a publications in the publication view all authors that collaborated on the publications are highlighted in the author collaboration view (Figure 6.7).

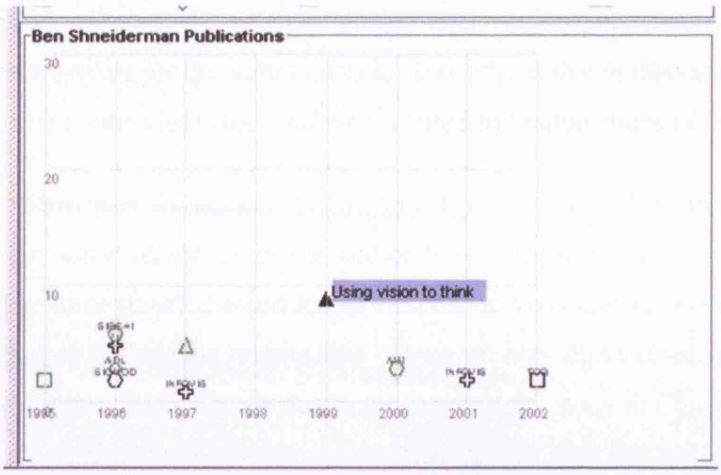


Figure 6.10 Publication view

6.5.4 Citation views

There are two main citation views, the publication citation view (Area AD) and the author citation view (Area BD). The publication citation view is activated as the user selects a publication and drags it into the publication citation view. The same applies to the author citation view where the user selects an author node and drags it into the author citation view.

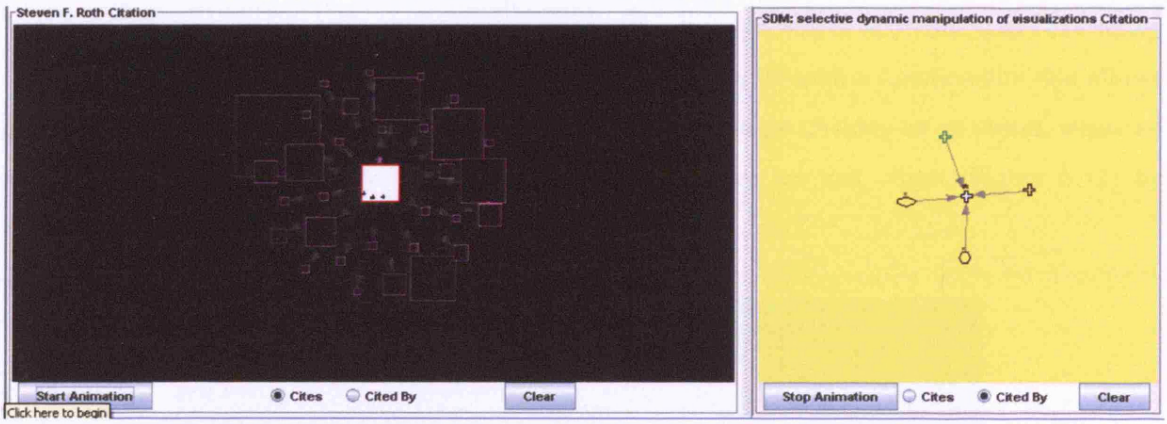


Figure 6.11 Author and publication citation views

As explained in Section 6.3.2 the citation relationship is a directed relationship. Hence, two toggle buttons are located at the bottom of these views (Figure 6.11). This would allow the users to determine whether they are interested in 'cites' or 'cited by' information. Only one level of citation is visible, direct citation, for reasons discussed above. For example the user drags one of Roth's papers into the publication citation view, and is interested in the 'cited by' relationship, i.e. all publications that cite it. This is indicated by the direction of the arrows. If the user needs to go

deeper into the citation tree then the user can double click on the publications and an additional level is revealed. Same applies for the author citation view, expect that in this case the user is able to see all authors that have publications that 'cite' or are 'cited-by' publications of that author.

Both views have a 'Stop/Start Animation' button and 'Clear' button. The 'Stop/Start Animation' button is used for the same reason as in the author view, due to the fact that a force-directed algorithm is used. The force directed algorithm in the citation view clusters node, either authors or publications, according to the citation relationship. However, only direct citations of a source node are viewed at a time (Figure 6.11). This is due to the fact that the study in Chapter 5 have revealed that when researchers interact with citation information do not look for the general picture, but instead tend to follow citation trails step by step. For example, the researcher may be interested in a paper published by author X and hence looks at the citations of that paper and expresses interest in a specific paper published by author Y and then goes on to look at that paper. Details on how this was implemented are explained in Section (6.7). The 'Clear' button as the name implies is used to clear the associated views. If the user does not clear the views then the displayed information will remain until alternative citation information is explicitly requested by the user.

6.5.5 Personalization of knowledge

In order to address the idea of personalization the approach taken was to allow the users to overlay the visualization with the user's personal views. This was done through a functionality that allows the users to mark authors or publications of interest. Simply by right clicking on an object, where an author or a publication the user adds a green contouring box on that object (Figure 6.12) by selecting the marking option from a pop-up menu.

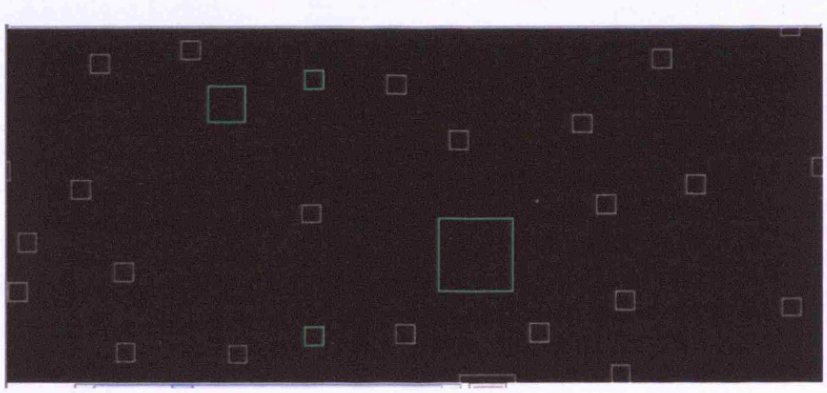


Figure 6.12 Marked authors have a green surrounding box

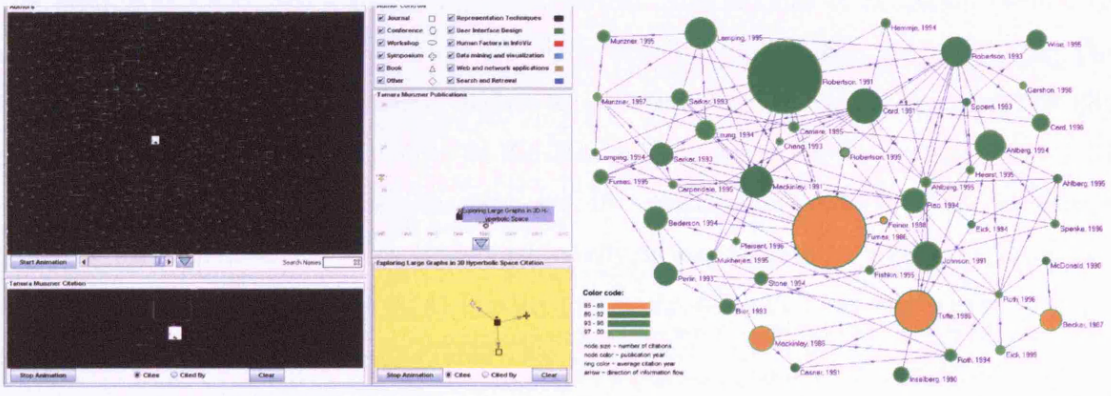
When users mark a publication the associated authors are also marked. This is due to the fact that the author view is used as the main navigation view. Marking the publication's authors in association with marking the publication allows users to relocate the marked publication. In addition, if an entity is marked in one view it will appear as marked in the other views. For example, if a user marks a publication in the publications view, whenever this publication is displayed in the citation view then it will appear as marked, and vice versa. The same applies for marking the author entities. The marking tool addressed the personalization factor based because there is no specific meaning associated with the marking color. This is kept for the users' own subjective interpretation. The effectiveness of this will be revealed as part of Chapter 9.

6.6 ALD and Literature Visualizations

In Chapter 4 an overview of academic literature visualizations was given, where research in this field was categorized into two categories: The KDViz and IR tools. In order to place the ALD InfoVis tool within the context of academic literature InfoVis tool the ALD InfoVis tool will be compared with KDViz tools and IR tools.

6.6.1 KDViz

As indicated in Chapter 4, KDViz tools tend to give a global picture of the entire Literature domain from a certain perspective. This is due to the specific needs of the domain analysts which in most cases, as we have identified, are the developers themselves.



(a) (b)

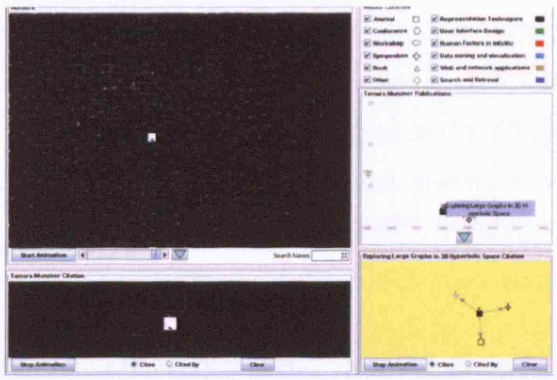
Figure 6.13.Compare the Literature Visualization Tool and KDViz (a) LV visualization tool (b) Ke (Ke et al, 2004) visualization submitted for the InfoVis 2004 contest , nodes represent the papers, color of the nodes represent the publication year and the size of the node represents the number of citation a paper gets.

The literature sensemaking experience is subjective. Hence, presenting users with pre-analyzed representations of literature data as in KDViz will communicate certain pictures of the domain. In addition, most of these visualizations introduce thresholds to clean up the data and generate global domain visualizations (Chapter 4). This does not comply with the findings of the requirement study (Chapter 5) where we identified that each individual domain entity is crucial to the experience, for example certain entities may be important to certain users and not others.

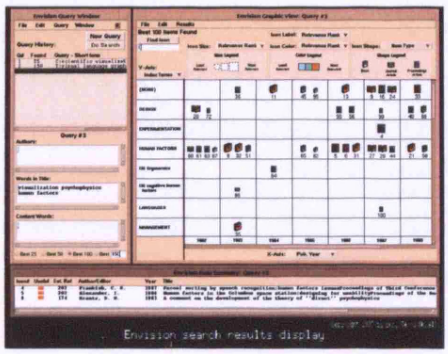
It can be noticed that ALD InfoVis tool (Figure 6.13 (a)) differs in its look and feel from the visualization that was produced by Ke et al (2004) which was submitted to the InfoVis 2004 contest (Figure 6.13 (b)). This visualization was chosen as a comparative example since it was developed to represent the same dataset. The development process of the visualization presented in Figure 6.13 (b) is similar to the KDViz development process presented in Chapter 4. The ALD InfoVis tool's main view can be compared to the KDViz visualization tool (Figure 6.13) as it represents clusters which might be used to understand the overall structure of the community. However, the difference lies in that the users when interacting with ALD InfoVis tool are able to dig deeper into the domain, and not merely interact with the surface (overview) as with the KDViz tool.

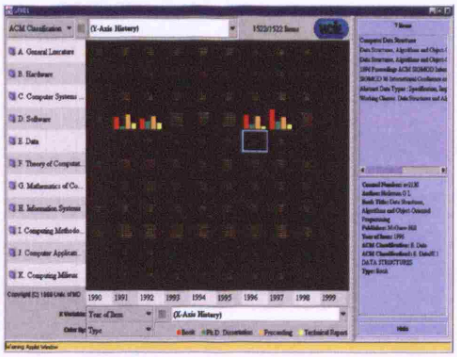
6.6.2 IR tools

As seen in Chapter 4, the IR visualization tools are tools that differ in the information that they reveal where the emphasis is on the tools rather than the data that they reveal. The ALD InfoVis tool is compared with two of the IR visualizations explained in Chapter 4: Envision (Figure 6.14 (b)) (Nowell et al, 1996) and GRIDL (Figure 6. 14 (c)) (Shneiderman et al, 2000). From a first glance it is evident that all have similar feel especially when it comes to their interactivity. All three visualizations (Figure 6.14) use dynamic queries as an interaction mechanism, meaning that all of these visualizations are highly interactive in the manipulative sense, unlike the KDViz tool. The major difference between ALD InfoVis tool and IR visualization tools is in the information portrayed by the tool, as ALD InfoVis tool relied heavily on user's literature domain experiences, as seen in this chapter. By comparing ALD InfoVis tool to the other IR tools represented in (Figure 6.14 (b), (c)) differences are generated (Table 6.5).



(a)





(b) (c)

Figure 6.14 Compare ALD InfoVis to IR visualization tools (a) ALD InfoVis (b) Envision (c) GRIDL

Concrete Entities	ALD InfoVis tool	Envision	GRIDL
Entities			
Authors	Yes	Yes	Yes
Publications	Yes	Yes	Yes
Publication details (title, abstract, keywords, et)	Yes	Only bibliographic summary (authors, year, title)	No
Source (Journal, book, et)	Yes	Yes	Yes
Interest	Yes	Yes	Yes
Relationships			
Collaborations	Yes	No	No
Citations	Yes	No	No
Author-publication relationships	Yes	No	No

Table 6.5.A comparison between ALD InfoVis, Envision, and GRIDL

Table 6.5 gives a brief comparison between ALD InfoVis tool, Envision and GRIDL. It can be noticed that most of these visualizations visualize the essential entities of any literature domain such as: author, document, source, etc. However, the major differences can be seen when it comes to visualizing the relationships: collaborations, citations and inter author-publication relationships. The

importance of these relationships is crucial to users' literature experiences. If it was not for the requirement gathering study (Chapter 5) it would not have been possible to identify the importance of these relationships. This re-emphasizes the point discussed in Chapter 4 that none of the IR tools can be used as part of our studies since they do not heavily rely on users' literature domain experiences which is crucial for this research. Before concluding the chapter, following is an overview of the means in which the code was developed through the use of the prefuse toolkit.

6.7 Technical Note: Prefuse and the ALD InfoVis Tool

Prefuse is an extensible software toolkit that helps developers in the creation of interactive InfoVis applications using the java programming language.

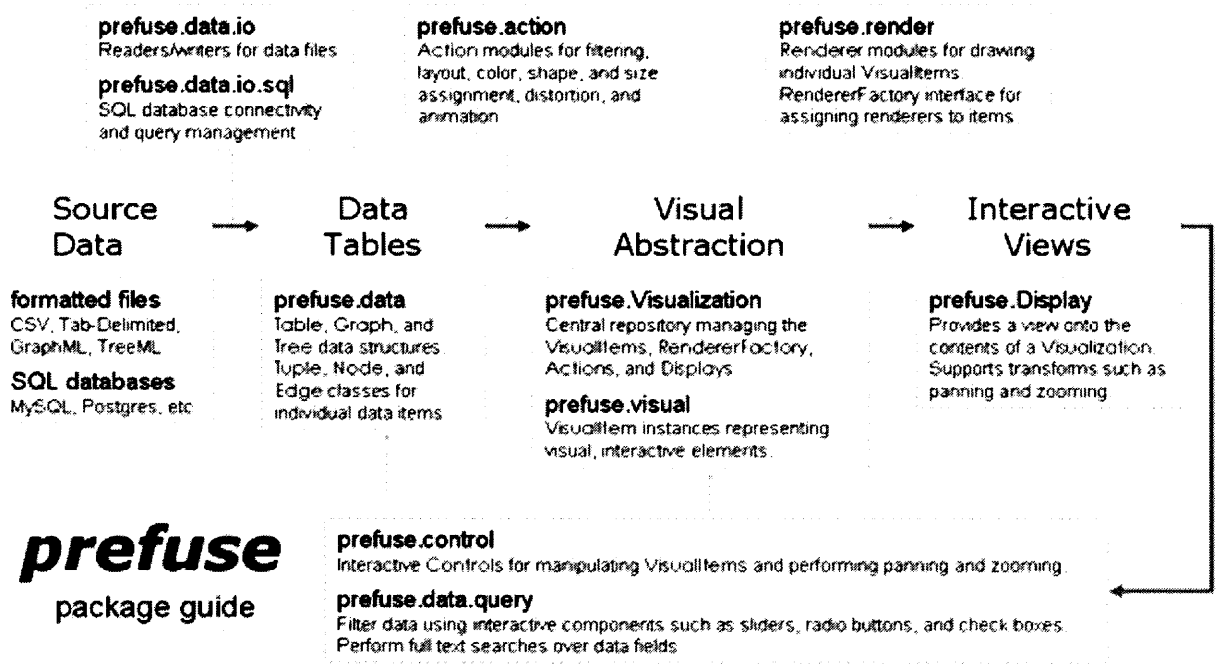


Figure 6.15 Diagram depicting the relation of different prefuse packages and classes to the infovis reference model (http://prefuse.org/doc/manual/introduction/structure)

Its design is based on the InfoVis reference model (referred to in Chapter 1 pp. 28, (Card et al, 1999)) where the visualization process is broken into four steps:

- Data transformation: the raw data is processed and stored into tables
- Visual mappings: visual mappings are mapped onto the data in order to give the data spatial and graphical properties

- View transformations: creation of views of the visual data
- Last but not least, human interaction where users interact with these interactive views

By looking at these steps from the perspective of the prefuse package guide we get the above figure (Figure 6.15). It illustrates the different packages and classes of the prefuse toolkit which implements the InfoVis reference model at the various stages.

- Data transformation: the collection of the source data to visualize is used to construct data tables of the data as it is to be visualized, this process might merely involve reading the data from a formatted database
- Visual mappings: the resulting data tables, which might be represented in the form of graphs or trees are then subject to visual mappings to create a visual abstraction, i.e. a data model that includes visual features such as spatial layout, colour, size and shape. The visual abstraction is responsible for containing all the information needed to draw a visual representation of the data.
- View transformation: the actual rendering of the data in the visual abstraction is done through the process of view transformations, in which rendering components draw the content of the visual abstraction into the visual view/s.
- User interaction with the visualization either through the mouse of the keyboard, feedback into this process causing changes or updates at any stage of the visualization pipeline, e.g. dragging an item, zooming into a view, etc.

The following is a detailed description of the general structure of the ALD application, from the perspective of these four steps, in order to give an overview of how prefuse was used as a toolkit to implement the tool. It is important to note that the functionalities explained here do not reflect all the functionalities provided by prefuse, it merely reflect that functionalities that have been used in order to develop the ALD InfoVis tool.

6.7.1 Data Transformations

The dataset used was downloaded in the form of an MS-Access database (Ke et al, 2004). A new database was created from the original one by importing essential tables which includes information about the authors and their associated articles, in addition to the citation information between

articles. This was done in order to increase the speed of the application when accessing the database, where by the needed tables and entities were ready to be imported by the application. New tables were generated from the original ones to satisfy the application needs, these are summarized as follows:

- A look up table was created which included the six interests and each interest was given a numerical id.
- A new table was created which contains information about articles from 1995 to 2002 sorted by year, as the original dataset has some articles that were not in that range. In addition each article was manually associated with an interest in addition with a source type (journal, book, conference, etc.)
- A table that contains the ids of the articles in the range of (1995 - 2002) and all the articles that it cites all grouped in one table.

As soon as the application is launched, the connection is made with the database and all the data from the tables are imported into two main lookup lists: an author list and an article list. The author list is a list of all author objects and the article list is a list of all article objects. These lists are used throughout the ALD application as they are used primarily to coordinate between the four different views of the application which were listed previously (Section 6.5.1): the authors view, the publication view, the publication citation view and the author citation view, by capturing any changes that occur in one view, which might affect the visual representation of the visual items in the other view.

After the creation of these lists the connection with the database is terminated. Hence, from this point forward all references to the dataset will be done using these lists. This is done in order to speedup the users' interaction with the application. Following the creation of the lists from the database some processing is done on the data that is stored in both lists in order to generate a few missing links which are necessary to create the various graphs:

- Citation links are generated between the articles, and between the authors
- Collaboration links are generate between the authors

This is seen clearly in the figure below (Figure 6.16), an author list is made out of many author objects; same applies to the article objects, where the article list is made out of many article objects.

Between the author objects and the article objects there is a many to many relation, where an author has multiple articles and an article is written by multiple authors. In addition, there are two many to many relation between the authors as each author collaborates with many other authors and each author is cited by many authors. Similarly, there is a many to many relation between articles, as each article cites many articles and may be cited by many articles.

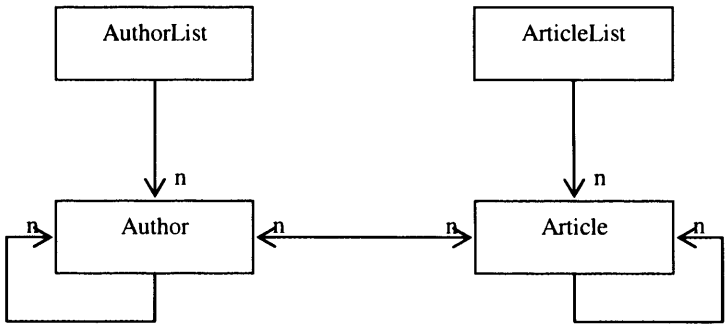


Figure 6.16 Author and Article class diagram

At this point the data processing is complete and the graphs are created. Three graphs are created:

- An author graph where the nodes represent the authors and the links represent the collaboration links
- An article citation graph where the nodes represent the articles and the links represents citation links between the articles
- An author citation graph, where the authors represent the authors and the links represent the citation links between authors.

All these graphs are created using the perfuse **Graph** data structure. As for the publications, a **Table** is created and not a graph for reasons explained in Section 6.3.1. This table however is only created when the publication view is activated as a result of the users' request. The reason the article citation graph and the author citation graph structures are created in the beginning and not upon the users' requests is due to the fact that the citations graph links all the nodes (authors or articles) of the dataset and it is only upon the users' request that parts of the citation graphs become visible, as will be explained in Section 6.7.5.

6.7.2 Visual Mappings

The visual abstractions of the graphs are created by adding them to the prefuse **Visualization** class. Four visualization classes are instantiated as part of the application, one for each of the views (author view, publication view, publication citation view and author citation view). For each node of the graph special instances are created known as **VisualItems** which are provided by prefuse kit, these incorporate both the visual attributes and the underlying original data values. Same applies for the edges, where **EdgeItems** are automatically created. There visual items incorporate visual information such as such as the x, y, coordinates, colour, shape size, and font of each of the visual items. The specific visual mappings of each of the visual items are provided by Action modules. These modules are processing modules for setting items visibility, computing layouts, assigning color values in addition to any number of processing tasks needed to be performed on to the visual items. All of the actions of the ALD application were customized by creating Action subclasses in order to provide application-specific processing tasks, except for the layout actions. Layout actions are used as provided by the prefuse kit. For the author, publication citation and author citation the **ForceDirectedLayout** is used, and for the publication view the **AxisLayout** is used for reasons explained in Section 6.3.1.

As for all the customized actions, the customization was done in order to coordinate between the various views. These customised actions constantly refer to the author and the article lists in order determine the author and article objects' status, i.e. whether the object was clicked, marked, whether it should be visible or invisible, etc, in views other than the one being processed. The following is a list of the actions that have been customized for the sake of this application with a brief description of each. The actions described here are mainly the ones used as part of the author view; they are explicitly stated here in order to give a better understanding of the means in which the prefuse toolkit was adapted in order to fill the specific application needs:

- AuthorStrokeColor: it is responsible for setting the stroke color of all the author node all stoke color is set to white except for the following conditions:
    - if any of the authors collaborators is selected in the author view then the authors stroke color is set to blue
    - For all other author visual items the transparency level takes into account the result of the visibility scrollbar

- AuthorColor: is responsible for setting the color of the author nodes it take into account various factors:
    - if the author is hovered then the author node is highlighted
    - if a publication of that author was clicked in the publication view then the author node is filled with white (same color as the publication background)
    - if a publication of the author was selected in the publication citation view then the author is filled in yellow (same color as the publication citation background)
    - if the author was selected in the author citation view then the author is filled with purple (same color as the author citation background)
    - if the author is selected in the author view then the author is filled with white.
- VisibilityAction: it responsible for the visibility of the author nodes which depends on the filtering conditions and whether or not he author is selected or a result of a search. If the author does not fit the filtering condition and is not selected nor is it a search result, then the author's visibility is set to true.
- AuthorLabelLayout: is responsible for setting the visibility and color if the author name labels.
    - If the author is selected in either the author in the author view is filled then the its name becomes visible and takes the same color as the author node
    - If the author view is zoomed in to a certain factor then the name label of the author is becomes visible.

All these have been set to run infinitely as long as the application is running. Similarly all actions of the other remaining views are customised to fit in with the applications needs.

6.7.3 Visual Transformation

The actual appearance of the visual items is determined by the **Renderer** modules. These are responsible for the actual drawing of the visual items. The ALD application uses the renderers

provided by the prefuse toolkit, more specifically the **AbstractShapeRenderer**, **EdgeRenderer,** and the **LabelRenderer**.

6.7.4 Interactive Views

Interactive views are provided by the **Display** component, which acts as a camera onto the content of a **Visualization**. The display draws all the items within the current view and can be panned, zoomed, and rotated as desired. The zooming and panning controls used by the ALD application are the ones provided by the prefuse toolkit. In addition, each display is supported by a number of interactive **Controls**, which process mouse or keyboard actions on the display in addition to the visual items. These are pre-built controls which are provided by the prefuse package which capture events such as clicking and dragging visual items. All controls used by the ALD applications have been customized to fit in with the application's specific needs and are created as subclass of the **ControlAdapter**, where methods such as **itemClicked** and **mouseClicked** have been overloaded. For example, when in the author view if a visual item is clicked, i.e. an author node, then the publication view is activated and all publications of that author are displayed in addition, all details of that author are represented as part of the text details view. On the other hand if the author is right-clicked, then the marking popup menu is displayed activated. From here, it can be seen that the activation of the various application views is dependent on users' interaction with the display, more specifically with the visual items of the visualization. Again, examples here have been given from the author view in order to give an idea of the means in which the **ControlAdapter** was adapter in order to fit with the application needs.

6.7.5 Prefuse independent adaptation

Using the prefuse toolkit facilitated the implementation needs and hence assisted in generating the main application. However, in addition to the adaptations to the toolkit, which were mentioned earlier, there were a few additional functionalities that needed to be coded from bottom up as the toolkit was not able to provide for them. This mainly related to the visibility of the citation graphs.

As mentioned earlier, the citation graphs are created as soon as the application is launched. However, they are only visually represented as the user activates their associated views. When the user activates these views this indicates that the user wants to see a specific part of the graph and not all of it. For example, if the user selects a publication and adds it into the publication citation view, this means that the user want to see all the publications that that particular publication cites.

Hence, the focus of the graph is set to be the publication of interest and only the publications that that publication cites or is cited by, depending on the user's request is set to visible. And as the user double clicks on the publication nodes in the publication citation graph the graph is expanded to show additional citation information. As the user double clicks again on that particular publication the graph is collapsed this is done by setting the nodes and edges visibility to true. Same applies for the author citation graph.

6.8 Conclusion

This chapter has introduced a methodical approach from which the design of the ALD InfoVis tool was established where the descriptive theory described in Chapter 5 formed the starting point from which the design process began. Each component of the visualization experience (visual and interactive) was given the same level of consideration and analysis, since they all play a major role in the realization of the final experience. Incorporating interaction into the design of an InfoVis affects the design of the externalization and its associated interface as it will set users' interaction scenarios. After the ALD InfoVis tool was implemented it was evaluated. The following chapter explains the study which evaluated the usability of the interface.

7. Evaluating the Usability of the Interface

7.1 Introduction

As discussed in Chapter 1 and reinforced in Chapter 3, the interface is an essential component in users' InfoVis experiences. Users are only able to accomplish their goals as a result of their interaction with the interface. As a result, before users' experiences can be addressed as part of this research it is necessary to evaluate the usability of the interface. If the interface is not usable then users' experiences will be affected negatively. The study conducted took the form of a standard usability study where the tool's efficiency, effectiveness and user satisfaction were captured. As in many interface usability studies, a task-based evaluation approach was taken. The aim of this study was to iron out traditional usability problems.

The study showed that the tool was effective when it came to answering the task related questions. The efficiency measure, on the other hand, which was based on the time it took users to accomplish their tasks, was unreliable. User satisfaction, which was captured using the Questionnaire of User Interface Satisfaction (QUIS), revealed that users were generally satisfied with the tool except for minor interface design issues which were mainly related to the difficulty in relating information across the various views, and the number of manipulative activities users had to engage with in order to accomplish a specific task. The results of this study led to a slight redesign of the tool's interface. In addition to evaluating the usability of the interface this study led to some insight into users' InfoVis experience.

7.2 Evaluating Information Visualization is a Challenge

One of the biggest challenges when it comes to InfoVis is related to its evaluation. Usability studies are essential when it comes to building InfoVis tools. This has recently been agreed upon by many of the InfoVis community. Even though usability studies are not a common practice when it comes to creating InfoVis tools, recent literature proves that it is becoming an emerging topic addressed by core members of the community. Chen (2005) listed the top ten unsolved problems in InfoVis and 'usability' took precedence in the list. Plaisant (2004) published a paper at the Advanced Visual Interfaces (AVI) international working conference titled *"The Challenge of Information*

Visualization Evaluation" in which she explicitly listed usability and user testing as one of the main challenges that are specific to InfoVis. More recently in 2008 a workshop titled "BEyond time and errors: novel evaLuation methods for Information Visualization" (BELIV'08) which was part of the CHI conference specifically addressed the challenges of evaluating visualization tools and discussed the explicit need for novel evaluation methods. This was a successor to the first BELIV workshop conducted in 2006 which was part of the AVI conference.

Various HCI evaluation methods are being applied in order to evaluate InfoVis tools such as: controlled task based studies, expert reviews (Tory & Moller, 2005), focus groups (Mazza, 2006), long-term case studies (Perer & Shneiderman, 2008), comparison studies either within a controlled experimental setting (Irani & Ware, 2003) or through case studies over long periods of time (Seo, 2006). However, these has not yet been an agreed upon methodology in relation to evaluating InfoVis tools, as a result, this research takes an experiential stance in order to evaluate the ALD InfoVis (Chapter 8). However, prior to capturing users' experiences a task-based evaluation study was conducted in order to evaluate the usability of the ALD InfoVis tool's interface, as the interface is an essential part of the experience (Chapter 1).

7.3 Evaluating the Interface

As discussed in Chapter 2 and Chapter 3, the two main activities that users engage with whilst interacting with InfoVis tools are cognitive sensemaking activities, and physical manipulative activities. These are an essential part of the experience and hence need to be taken into account when it comes to evaluating an interactive InfoVis tool. The approach taken was to give users a set of tasks based on visual taxonomies. This was inspired by seminal InfoVis evaluation studies. The generated tasks must fit within the context of the interface since the sensemaking activities, goal space, and manipulative activities, device space, cannot be separated (Chapter 1). It is through interacting with the interface that InfoVis knowledge can be gained. Hence, evaluating the InfoVis interface addresses both the externalization's visual language and the means by which it fits within the context of the interface.

7.3.1 Previous work: Visual taxonomies

When users first interact with the externalization they engage with low-level tasks such as: identify the author with the most publications. This information relies on visual syntactic knowledge where, for example, the size of the node refers to the number of publications. The user will need to interact

with the visual vocabulary in order to perform these tasks. Taxonomies have been proposed which address the categorization and organization of such low-level tasks. Some of these taxonomies are related to the type of the data such as the one proposed by Shneiderman (1996), where he proposed a task by data taxonomy for InfoVis that incorporates seven data types: 1D, 2D, 3D, temporal, multidimensional, tree and network, and accordingly identified seven tasks that the visualization must support. These tasks which are listed as: overview, zoom, filter, details-on-demand, relate, history and extract are interactive tasks that relate to the manipulative activities that users perform in order to interact with the visual representation.

On a lower-level, Zhou and Feiner (1998) identified general visual tasks for designing visual discourse. Visual tasks, in this case, lie midway between the intentions of the presentation: goals of the user when interacting with the visualization, and the visual techniques, such as: shading, color etc. These visual tasks are independent of the targeted domain; they can be considered abstract since they indicate a desired visual effect but are not as low-level as the visual techniques. Zhou and Feiner defined the visual tasks as: *"abstract visual techniques which can be achieved by a lower set of techniques"*. In addition, they characterized the visual tasks along two dimensions: *visual accomplishments* and *visual implications. Visual accomplishment* tasks reflect the tasks with which the intentions of the presentation are achieved, whereas the *visual implications* tasks reflect the techniques a visual task may imply. The *visual accomplishment tasks* are categorized into two main categories: visual tasks which are related to *informing* the user of the presentation's intentions, and visual tasks which *enable* the user to manipulate the presentation, hence incorporating both the visual and the physical activities. The *inform* categorization enables the user to gain a general overview of the represented domain, whereas the *enable* categorization incorporates tasks that allow the user to explore the visual representations, such as: searching for a specific element, verifying a specific fact. The generic visual tasks that this taxonomy categorized are:

- Reveal – expose an object or specify it
- Emphasize – reinforce an object by focusing on it
- Associate – form relation between two visual objects
- Background – contrast to separate object from the background
- Categorize – objects are in the same category grouped by similarity
- Cluster – objects are in the same cluster grouped by similarity
- Compare – show similarity or difference between objects
- Correlate – correlated objects imply a composite visual structure (share same visual attributes)
- Distinguish – distinguish between groups of objects spatially or perceptually
- Generalize – merging visual components together
- Identify – identify an object using one of its properties
- Locate – An object is visually located relative to another object

- Rank – objects are ordered by rank
- Switch – transition from one scene to another

These generic tasks are similar to the ones defined by Wehrend and Lewis (1990). These tasks are too generic to be used in an evaluation of an InfoVis tool. In order to address this, Morse et al (2000) used the visual tasks identified by Zhou and Feiner (1998) to devise low-level visualization tasks at the syntactic level of knowledge. In other words, they developed a procedure to map from this visual taxonomy into tasks. They argued that these tasks are an essential component which should be explicitly tested. Their argument is based upon the idea of 'de-featuring' the interface, where they map domain independent visual taxonomies to the specific visualization domain. From Zhou and Feiner's (1998) visual taxonomy, Morse et al (2000) identified a set of visual subtasks that are related to their domain of interest, which was Information Retrieval (IR).

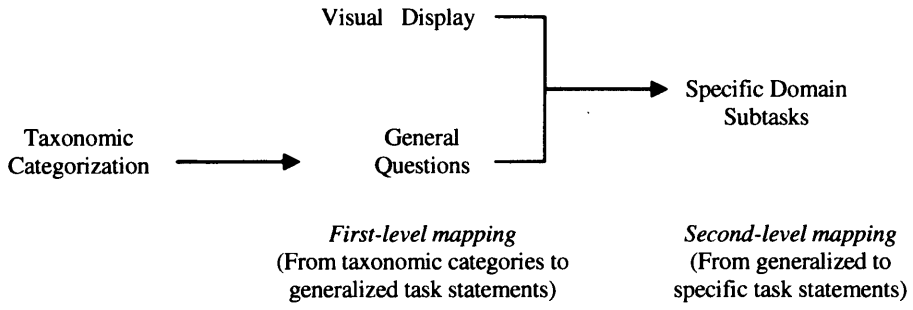


Figure 7.1 The experimental tasks generation process (Morse and Lewis, 2000)

Each visual task was mapped into tasks associated with the Information Retrieval (IR) domain. From there, generalised questions were devised (Figure 7.1). The generalized tasks underwent another level of mapping that transformed them into specific task statements which specifically depend on their relation to the represented domain. The generalized tasks are tasks that are not associated with a particular concrete domain entity, whereas the specific tasks are related to specific domain entities. An example of this is illustrated in the following table.

Type	Generalized task statements (Level 1)	Specific task statements (Level 2)	Terms
Compare	Which key term has the most documents about ONLY it?	Are there more documents that contain ONLY the term Romania or ONLY the term Czechoslovakia?	2-term
Associate	Which key term is associated with more documents?	Which is the most frequent key term in this set of documents? A. Vatican; B. Embassy, C. Noriegra	3-term

Table 7.1 Examples on generalized and specific tasks statements which were extracted from Morse and Lewis (2000)

Table 7.1 illustrates how Morse et al (2000) generated domain specific low-level tasks from primitive visual tasks. In this study, they did not test all the visual tasks revealed by Zhou and

Feiner (1998); instead they identified a set of tasks that varied significantly and were as broad as possible due to the study's time constraints. For each of the generalized tasks they generated two specific tasks that varied in difficulty. The difficulty measure they used was the number of terms represented in the task, as seen in Table 7.1.

Wiss and Carr (1999) also relied on low-level tasks as an evaluation measure. They performed an empirical study to compare three 3D InfoVis tools. In their evaluation they relied on the tasks defined by Shneiderman (1996): overview, zoom, filter, details-on-demand, relate, history, and extract, from which they devised a set of low-level tasks. Three of these tasks were chosen for the comparison study they performed, which were: overview, zoom and relate. For each of these tasks they defined associated low-level tasks which were relevant to the domain of interest, which in this study was a hierarchical file system. The low-level tasks they relied on are summarized as follows:

- For the overview task they designed *compare* tasks where users were required to compare two objects of interest.
- For the zoom task they designed *search* tasks that required the user to zoom in to the visualization to find the object of interest.
- For the relate task they designed *count* tasks that required the users to count the number of objects.

Zhou and Feiner's (1998) taxonomy gives a more diverse set of tasks when compared to the other taxonomies hence it will be relied on for evaluating the ALD InfoVis tool's externalization, where a similar approach as Morse et al (2000) was applied in order to generate the tasks that were used as part of the evaluation study.

7.3.2 Tasks generation

In order to evaluate the externalization of the interface a similar approach as Morse et al (2000) was taken, where tasks based on Zhou and Feiner's (1998) visual taxonomy were generated. A subset of Zhou and Feiner's generic low-level tasks which best represented the tools' design rationale (Chapter 6) were decided upon, these are: *locate*, *identify*, *associate*, *categorise*, *rank*, *compare*, *emphasize*, *distinguish*, *reveal*, *cluster*, *correlate* and *generalize*. The remaining tasks: *background* and *switch* were not used as they did not fall within the context of the interface design since the four views of the ALD InfoVis tool remain the same as there is no switching between views or backgrounds (Chapter 6). The 2-level mapping technique was used, as in Morse et al (2000)

(Figure 7.1), from which general task statements and specific task statements were generated as depicted in Table 7.2.

Type	Generalized task statements (Level 1)	Specific task statements (Level 2)
Rank	Rank these authors [author_name1, author_name2 ...] according to a condition, where status = number of citations.	Rank *Shneiderman* and *Pirolli* according to the highest status paper. (Status = number of citations)
Correlate	Of all the authors that cite/collaborate [author_name] who has collaborated with/ cited him/her?	Of the authors that cited *Peter Krogh*, three of them collaborated with him. Can you identify which ones?

Table 7.2 Generalized and specific tasks

The specific task statements were grounded in the results of the qualitative requirements study conducted, discussed in Chapter 5. These activities are summarized as follows:

- Identify collaboration relationships between authors
- Identify the publications of an author
- Reveal the citation relationships between authors and the citation relationships between publications
- Identify the number of publications associated with an author
- Identify the number of citations associated with a publication
- Interact with the details of the paper such as reading the abstract and the keyword, etc.

These activities were associated with the visual tasks in order to generate the general task statements. Next, these tasks were associated with specific domain related entities in order to generate specific task statements. In addition, tasks that tested the ability of users to identify nested relationships (Table 7.2) were identified. A complete list of the generated tasks can be found in Appendix B.

As discussed in the Section 7.3.1, Morse et al (2000) categorized the tasks according to the level of difficulty which was based on the number of terms. This research, on the other hand, is not interested in such difficulty levels as the requirements analysis study (Chapter 5) did not reflect such a need. The number of terms is not a key element in the design rationale of the visualization tool (Chapter 6). For example, if two tasks were associated with each visual task, each with a varying number of terms, then this will not give additional information about the interface nor the visual representation; it will only cause the user to repeat the same activity multiple times. For example, if we had an additional task associated with the *rank* task (Table 7.2) with 3 terms instead of two, such as: *Rank [author_name1], [author_name2] and [author_name3] according to the highest status paper*, users would have to locate each of the specified authors and accordingly

identify the highest status paper, which is a repetition of the same primitive actions as if only two terms were used.

Difficulty	Visual tasks	Activities
Primitive	Locate, identify, associate	Simple physical activities and visual syntax recognition
Intermediate	Categorise, rank, compare, distinguish, reveal, emphasize, cluster, correlate	Combination of physical activities and visual syntax recognition
Complex	Generalise	Combination of physical activities and an attempt at semantic knowledge

Table 7.3 Difficulty levels and their associated visual task

In this study the tasks were categorized according to the primitiveness of the actions the users engage with in order to accomplish a specific task, which in turn relates to the complexity of the visual language syntax as presented.. The reason for doing so is that in addition to identifying usability problems which are related to the externalization, this study is also interested in identifying usability problems which relate to users' interaction model (Chapter 3) and the associated manipulative activities. Visual tasks are ranked into three levels based on their primitiveness, as seen in Table 7.3, which are: primitive, intermediate and complex. Following is an overview of each.

Primitive tasks

With the primitive tasks, users engage in basic visual syntax tasks such as understanding the meaning of the visual vocabulary, in addition to engaging with a small number of manipulative activities in order to execute these tasks such a click or a drag. The following tasks were ranked as primitive:

- *Locate* tasks: assist in determining whether or not the user understands the visual data layout since it is essential that they are able to locate specific entities. For example: *Locate [author_name]'s 2001 paper, what are its keywords?*

- *Identify* tasks: assist in determining whether the user is able to understand the visual encodings, such as shape and color, which are used to encode the data. For Example: *Of the papers that have been published by [author_name] which has been cited the most?*

- *Associate* tasks: assists in determining whether the user understands the relationships between the various visual entities. For Example: *Which research interest is associated with more authors?* Or the association between an author and a specific conference or symposium.

Intermediate tasks

From primitive actions more complex actions were identified based on Zhou and Feiner's visual taxonomies: *categorize*, *rank*, *compare*, *distinguish*, *reveal*, *cluster* and *compare*. The categorization was based on the fact that in order for the user to be able to accomplish any of these actions one or more of the primitive actions must be executed and hence the user must engage in multiple manipulative activities. For example: *The [year] [paper_title] by [author_name] cites another paper by [author_name], who does the latter paper cite?* This is an intermediate revelation task since it is made out of various primitive actions. In order for the user to accomplish this task the user must first locate and click on the particular author, identify the specific paper and then reveal its citation information by dragging it into the paper citation view. It is only then that the user will be able to accomplish the task.

Complex tasks

Complex tasks lean more towards the high-level tasks since they are based on users' exploration of the visualization and not on specifics. They are less controlling compared to the primitive or the intermediate tasks in terms of the actions that the user must execute, and the answers they provide. Complex tasks are mostly related to the *generalize* visual task. For example: *What is the relationship between the following authors [author_name] and [author_name]?* Unlike with primitive or intermediate tasks, where the user is restricted with the ways in which to explore the externalization, with these complex higher-level tasks the users are given the freedom to explore the represented domain and engage in higher level of thinking. Different users can reach different results in various ways. For example, during the course of the study one of the users identified a relationship between two authors that the researcher had not previously come across despite extensive knowledge of the dataset.

Before explaining the study, it is essential to note that the 'marking tool' explained in Chapter 6 was not targeted by the generated tasks because it did not fit with the context of the visual taxonomy in addition to the format of the study. The study was designed in order to evaluate the usability of the interface which relied on restrictive well defined tasks. This does not comply with the design rationale of the 'marking tool' as it is designed to support users in their subjective domain related sensemaking activities. The effectiveness of such a tool is addressed in detail in Chapter 9.

7.4 Interface Usability Study

The usability study conducted took the form of a task-based study, where the tasks used were the ones described in Section 7.3. These were tested within the context of the interface. The measures used to evaluate the usability of the tool were: effectiveness which related to user's ability to correctly accomplish the tasks, efficiency which was based on the time it took users to accomplish the tasks and user satisfaction with the interface which was based on the QUIS.

7.4.1 Aim and objectives

The aim of this study was to evaluate the usability of the interface. Within the context of InfoVis the interface is not merely made out of manipulative functionalities but also visual externalizations of the data (Chapter 2). As a result, two objectives are addressed, identifying whether the visual language used by the tool is understandable by the user, and determining the usability of the associated manipulative functionalities.

7.4.2 Study design

Standard HCI practice tends to capture some or all of the following (Frøkjær, Hertzum, & Hornbaek, 2000): the effectiveness of the system in assisting the users to accomplish their tasks, the efficiency of the system through a specific efficiency measure which in most cases is represented by the time it takes to accomplish a task, and last but not least capture the general subjective user satisfaction. As a result, the usability study was designed to address these three perspectives. In addition to relying on these measures, users' comments and observations were noted by the researcher. Prior to beginning the study demographic information was gathered in addition to participants' knowledge and experiences with InfoVis tools in general and literature visualization tools in particular. Users were given fifteen minutes training where the researcher explained the system to them in detail, and participants were given the opportunity to interact with the system through the set of previously generated tasks. A total of 22 tasks were generated; these can be found in Appendix B. The tasks were presented to the users in order of difficulty reflecting cumulative familiarity and knowledge of how the interface worked. During the course of the study the researcher took notes in addition to measuring the time participants needed to answer each question.

7.4.3 Participants

For this study the intention was to recruit participants with diverse knowledge and experiences with the literature domain as they form the target audiences, which are researchers. Only a small number of participants were needed since the aim of the study was to filter out interface related usability problems. Robertson (2008) has indicated that a total number of about five users have been shown to be sufficient for discovering major usability problems with a new visualization's interface.There were seven participants in total. This number was sufficient for revealing major usability problems (Neilsen, 1995). In addition it has also allowed for the exploration of the mismatch with a more effective InfoVis evaluation. There were two women and five men whose ages ranged between 22 and 51. All participants had more than 10 years computer experience except for one who had 5 to 10 years experience. Five of the participants had 2 to 3 years experience in academic research, one had 3 to 5 years and one had none. The participant with no research experience expressed interest in learning about the InfoVis field and hence seemed a good candidate to represent a novice researcher. This participant showed great enthusiasm during the study. Five of the participants knew what InfoVis was; four have previously worked with visualization tools. Two participants had knowledge of the InfoVis literature, one of which was an expert in the field. None of the participants used the InfoVis tools to work with academic literature. All participants had an HCI background except for 2 who had a computer science background. No association was found between the background of the participants and their performances. This might be due to the nature of the tasks that were given to the participants, which targeted the ability of the participants to understand the visual language and interaction model of the interface.

7.4.4 Materials and methods

The system prototype was running on a 2004 Toshiba laptop with 512 MB RAM and 1.70 GHz processor. As indicated, the measures that were relied on in order to capture the usability of the interface were: effectiveness, efficiency and user satisfactions. Following is a description of the materials and methods used to capture each.

Effectiveness

Performance was measured by the correctness of the answers that users provided for each of the tasks which were scored out of 3. If the user answered the question correctly it was scored as a 3, if only part of the question was answered then 1 or 2 was given depending on the answer. The score of

2 was given if the answer to the question is partially correct, for example if the task requests the user to give the title of the paper and the research interest of the paper and the user merely gives the title. A score of 1 was given if the answer to the question was incorrect due to the misinterpretation of the question. For example, if the question asks about the type of a particular paper and the user identified the paper correctly but wrote down the title of that paper instead of the type. Common mistakes made by the users were noted and scored in a consistent manner. A score of 0 was given if the answer was incorrect.

Efficiency

The efficiency of the tool was captured by the time it took users to accomplish a task. The timer was started as soon as the user started interacting with the tool and stopped as soon as the user started to write the answer to the tasks on the task sheet paper. A SonyEricsson Z610i stopwatch was used.

User satisfaction

User satisfaction was captured using the QUIS (Chin, Diehl & K. L. Norman, 1988) questionnaire, which is a reputable and reliable questionnaire that has been used by prominent researchers in the field of InfoVis, e.g. (Ahlberg, Williamson & Shneiderman, 1992). The aim of this questionnaire was to capture users' general satisfaction. Relying on standard satisfaction questionnaires, such as QUIS, has been proven to give more reliable results than homegrown ones (Hornbaek & Law, 2007). The questionnaire measured overall users' reaction to the system in addition to users' reaction to nine interface features. Only users' reaction to: screen factors, learning features, system capabilities, and color was captured. The other features which were: on-line tutorials, multimedia and teleconferencing were omitted from the questionnaire since they did not fit with the characteristics of the tool. QUIS uses a 9-point scale for each of the questionnaire related questions. The questionnaire is presented as part of appendix B.

7.5 Analysis

The analysis of the generated data reflected by the effectiveness, efficiency and user satisfaction assisted in effectively evaluating the interface of the ALD InfoVis tool. Following is a detailed description of each.

7.5.1 Effectiveness: User performance

All participants managed to give answers to all of the 22 questions even though in certain cases they used different means: the manipulative activities with which they engaged. For example, one of the tasks given to the users was: *Benjamin B. Bederson's* 1995 higher status paper is cited by one of his collaborators, identify which one? (Status: number of citations)

User	Total/66
U1	62
U2	64
U3	60
U4	61
U5	58
U6	61
U7	62

Table 7.4 Users performance (22 tasks each corrected out of 3)

Tasks	Average Performance
Primitive	
1	3
2	1.7
3	3
4	3
5	2.9
6	2.7
Intermediate	
7	2.9
8	3
9	2.1
10	2.9
11	3
12	3
13	2.7
14	2.6
15	2.6
16	3
17	2.9
Complex	
18	3
19	3
20	2.7
21	3
22	3

Table 7.5 Tasks average performance (each question is corrected out of 3)

In order to answer this question different users engaged in different interactive activities. One of the users answered this question by placing Bederson's 1995 paper into the paper citation view and clicking on each of the papers that cites Bederson's paper to identify its authors and determine whether or not they collaborated with him. Another user used the combination of the publication-citation and author-citation view to identify the collaborators. Both of these users answered the question correctly, which points to the flexibility of the tool. Users' performance was extremely good, as seen in Table 7.4. This indicates that the visual cues represented by the system were understandable by the users based on the fact that the tasks that the users performed were devised from a visual taxonomy, as indicated in Section 7.3.

Table 7.5 lists the average performance of the users for each of the 22 questions given. From here two tasks were identified where users consistently performed badly, these tasks are tasks 2 and 9:

Task 2: If Shneiderman had a new publication written in 2002 and was cited 25 times where would it be located on the screen?

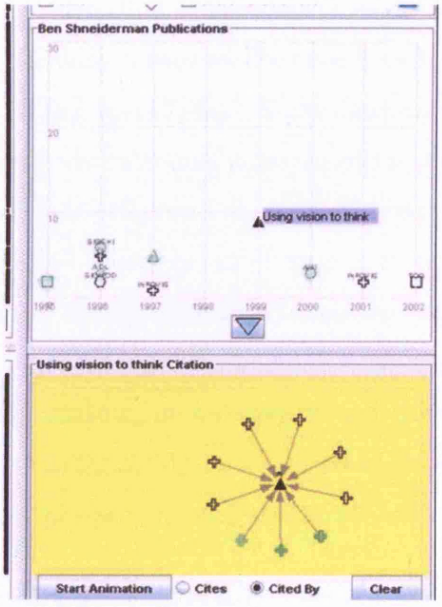


Figure 7.2 Publication view (top) publication citation view (bottom)

The correct answer is: it would be located in the publication view where x = 2002 and y = 25. Only one participant answered this question correctly whereas the rest were confused and were not able to do so. This is related to the wording of the questions since during the study the participants asked the researcher to explain the question. It is also related to the fact that some participants forgot the meaning of the y axis which indicates the number of times a publication was cited (Figure 7.2,

above). Later behaviour of those participants indicated that instead of using the publication layout to identify the number of times a publication was cited, they counted the number of times a publication was cited in the publication citation view (Figure 7.2).

Task 9: How many papers written by Bederson does his 1999 paper cite?

The correct answer is 1. Most users got the answer wrong due to the wording of the question. Most of them answered 6 which indicate the number of times Bederson's 1999 paper was cited. They did not understand that the question was looking for the number of self-citations.

Interestingly, most of the complex questions were answered correctly by the participants. This might be due to the fact that these tasks came last in the list of questions, hence bridging the learning curve. In addition, it might be hinting towards the fact that non-restrictive tasks allowed for subjective experiences in which users started to move beyond the interface and into reasoning about and understanding the data.

7.5.2 Efficiency: Physical activities

There was not a consistent correlation between the time it took users to accomplish a specific task and the how well they did on that specific task. Some users accomplished certain tasks faster than others, as some users took different reasoning paths, as will be explained next. Hence, it can be said that time may not be an efficient efficiency measure. Yet, due to the number of participants this cannot be claimed with certainty. However, an interesting factor was identified that might be used as a representative of efficiency which was related to the physical activities that users engaged with. Through careful observations of the users it seemed that the more they engaged with manipulative activities such as: constantly clicking, or zooming in and zooming out to accomplish something specific the more they were frustrated. This was identified through the comments users made, the facial expressions or gestures they performed. For example, one user commented:

> *"if there were a lot you had to manually search through all the different names to find the one you were looking for"*

In this example the user had to constantly be clicking on visual entities to reveal the information. One may argue that this is similar to time in that the more activities they engage with the longer it would take to accomplish the task. This is true in certain cases, however when it comes to the complex tasks it is not. Complex tasks, as described above, are high-level unrestrictive tasks through which users need to reason and explore. Hence, the time it took users to accomplish such a

task depended on the path that they choose to proceed with, in addition to the amount of exploration. For example, users were given the task of identifying the relationships between two authors.

User	Time (sec)	Identified Relationships
U1	74.2	Collaboration on one paper
U2	16.3	Citation relationship
U3	37.4	Collaboration relationship
U4	24.2	Collaboration on two papers
U5	54.5	Two way citation
U6	64.5	Collaboration on one paper
U7	25.2	Collaboration on two papers

Table 7.6 User' performance on the complex tasks

As seen in Table 7.6, not all users reached the same conclusion. Some users identified that the relationship between the authors was based on a collaboration relationship, others identified that it was based on a citation relation. In fact some users pointed to the specific publications on which the relationship was based. The table also shows that u1 and u6 took the longest. From observation this was due to the fact that they took a long path to identify the relationship and were exploring the visualization from multiple angles until they accomplished the task. Hence, from here it can be seen that time, as an efficiency measure, might be suitable to assess the efficiency of the interface. However, when it came to complex, high-level, tasks it is not an appropriate measure. In addition, the study is hinting towards the need to consider the physical activities that the user is executing as part of the efficiency measures of the tool.

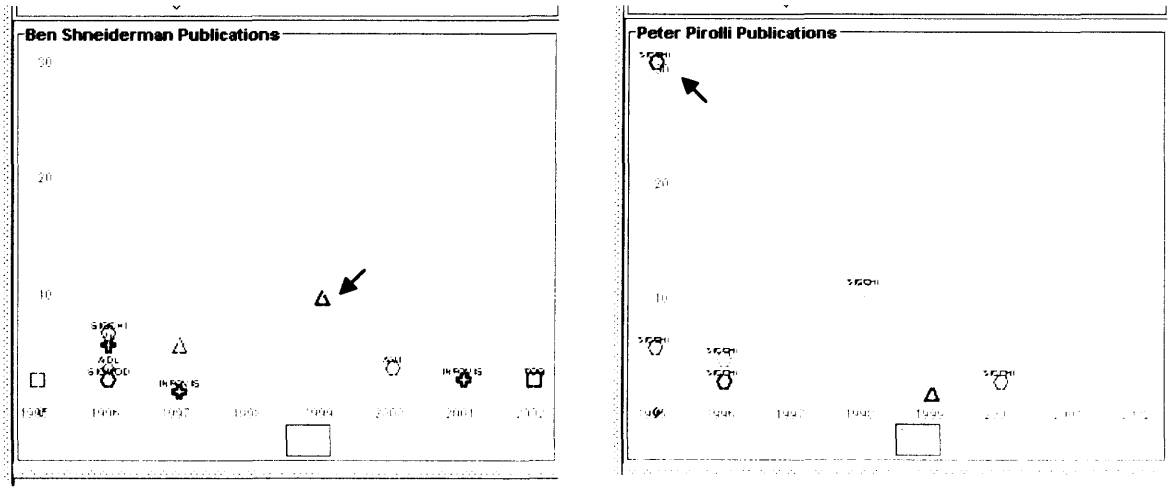


Figure 7.3 Ranking authors publications

For example: during the course of the study users were given the following tasks: Rank Shneiderman and Pirolli according to the highest status publication. (Status = number of citations)

In order to perform this task efficiently the user clicks on the authors and identifies the location of the publications on the y-axis, since it is related to the number of times the papers were cited, and compare the authors accordingly (Figure 7.3). However, during the experiment one of the users forgot that and instead inserted each of the authors' publications into the citation view and counted the number of times that each paper was cited. This was a very frustrating experience for the user. Using the manipulative activities as an efficiency measure and its relation with the overall user InfoVis experience is a factor that needs further investigation.

7.5.3 User Satisfaction: QUIS analysis

At the end of the study users were given the QUIS. The following is an overview of users' ratings of the tested system features, in addition to user's comments on each of the interface features. These comments were captured from the questionnaire as users were asked to write comments on each of the features that they were rating. The tables including users' ratings of each of the features on the 9-point scale, included in Appendix B.

Overall reaction

Users' overall reaction to the system was above average: they all felt that the tool was very stimulating and quite flexible. The major issue identified with their overall reaction was that they thought that it was quite hard. All users rated screen layout as being above average. Most users rated the use of various views and the ability to relate information between views as being above average, except for one user which indicated that this feature was quite confusing. Most users had a problem with the character font sizes where they indicated that this made it quite difficult to read. This problem is quite common with InfoVis tools due to the size of the display and the amount of information displayed on the screen. Most users commented that the most challenging screen feature was associated with their ability to relate the information displayed in the various views. For example:

> U2: *"The relationship between screens may need a bit of clarification a tip or reminder may be useful"*
>
> U3: *"More work on views and pointing out the relationships between views might be useful."*

Learning

When it came to users' ability to learn to operate the interface, the questionnaire indicated that this was neutral. The questionnaire also revealed that user's ability to explore features of the interface was above average. Most users indicated that they were able to remember the use of commands except for two users. Most users indicated that they were able to perform tasks in a straightforward manner. In addition, in relation to learning to operate the interface, analysis indicated that the main problem was again related to their ability to relate information in the various views, for example U4 commented:

> *"Sometimes was hard to remember the relationships"*

System capabilities

The questionnaire indicated that users felt that the system was reliable and that they could easily correct their mistakes. It also indicated that the ease of operating the system depended mainly on their level of experience with the tool, which might be an indication as to why users performed better in the complex tasks. In addition, some users expressed concerns with the speed of the tool in certain scenarios, since it appeared to be too slow when representing large author citation graphs. This is due to the capabilities of the computer. For example U4 commented:

> *"Biggest challenge presented was slow response time which made the animations not as smooth as one would desire."*

Color

The QUIS analysis indicated that users felt that the colors used were clear and understandable; however when it came to the publication view it was difficult to see, for example:

> U1: *"I had difficulty making out a small yellow cross on the white background."*
>
> U7: *"I found the colours a little difficult to distinguish".*

From the study it was apparent that rating the system through previously designed questions did not reflect the feelings that the user has of the interactive experience. Only a glimpse of users' feelings was generated through the comments that they gave:

> *"I think I would have a different appreciation of the system if it meant something and helped me"*

Here, the user indicates that his/her satisfaction is affected by the familiarity of the domain, which the QUIS failed to address.

7.5.4 User comments

At the end of the study users were asked if they would use the system for exploring literature information; all said 'yes' except for one. He indicated that he would prefer to use a list rather than a visual representation. In addition, users were asked to give general comments about their experience using the system. Many of the usability issues that the questionnaire revealed were also identified through these comments. These were mainly related to the problems they were facing with relating information in various views. For example:

U6: *"Establishing links between the entities"*

U2: *"When looking through nested citations and collaborations"*

They are referring the fact that various views must be used in order to look at the relationships between the citation and collaboration information (Chapter 6). Users preferred to have most information displayed in one view rather than having to look for it in multiple views, for example user U3 commented that he would like to:

"Include author names on tool tip descriptors of papers".

Users commented on some usability problems that were related to the manipulative activities, which were not revealed by the questionnaire such as the idea of incorporating an auto-zoom facility related with the search feature so that they would not have to zoom-in and out to locate the search results. In other words, change the focus of the visualization automatically without having to physically zoom in or out. This relates back to the relationship between the number of physical activities and the efficiency of the tool. In addition, some users commented that the physical activity of zooming in and out were not natural and wanted the two actions swapped.

U4: "Would swap the zoom/scroll wheel mappings"

U7: "I regularly zoomed out rather than in..."

This was due to the fact that in order to zoom in the user needs to drag the wheel back and in order to zoom out the user pushes the wheel forward (Chapter 6).

From the above discussion it can be observed that the major problem with the usability of the interface was related to the ability of the users in relating the information in the various views, in

addition to the number of manipulative activities that they had to engage with in order to accomplish specific tasks. These are addressed in the redesign of the tool which is discussed next.

7.6 Redesign

As a result of the usability study, the ALD InfoVis tool underwent a slight redesign which affected the functionality of the tool and consequently the design of its interface.

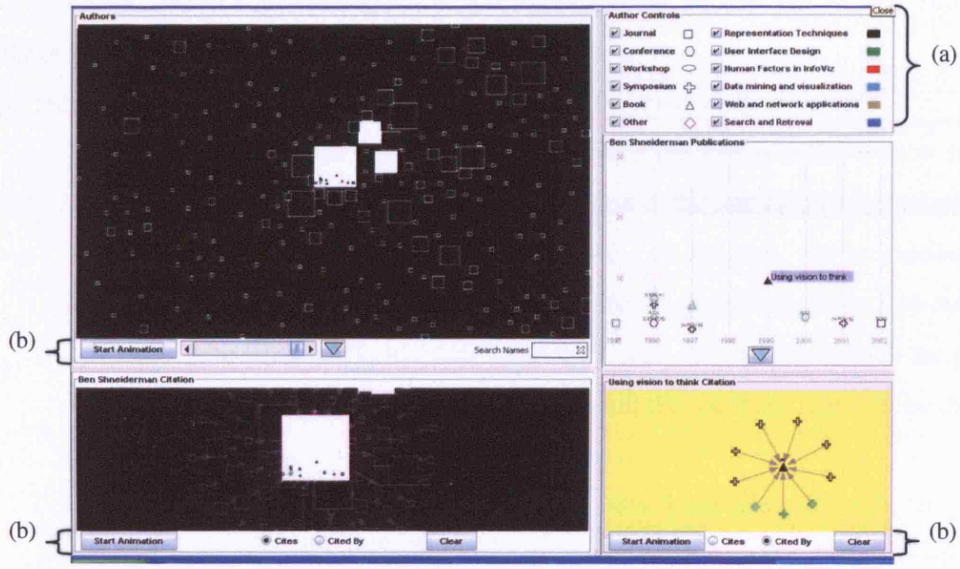


Figure 7.4 The ALD InfoVis tool – prototype 1 (a) the filtering tools (b) view manipulation tools

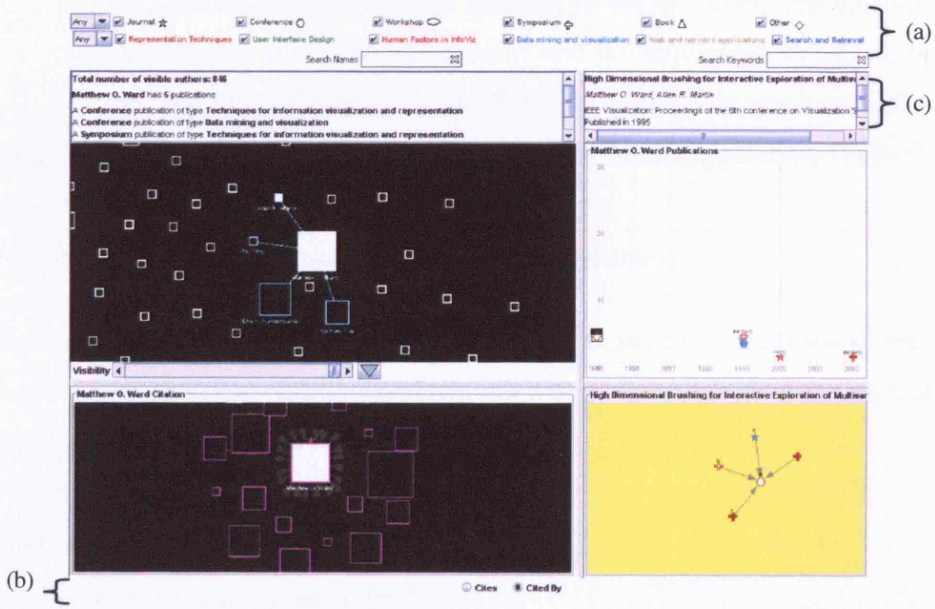


Figure 7.5 The ALD InfoVis tool – prototype 2 (a) the filtering and searching tools (b) the citation views' tools (c) the text details view

However, before explaining the functionality redesign in detail an overview of the changes that have been made to the interface are presented. Figure 7.4 identifies the areas that have been affected in the initial prototype. These are mainly the filtering area (Figure 7.4 (a)) and the view manipulation functionality area (Figure 7.4(b)).

Figure 7.5 is a snapshot of the second prototype that resulted from the redesign of the first (Figure 7.4). The differences are summarized as follows:

- The filtering functionality (Area a) – has been moved to the top of the screen and incorporated the searching tools (name and keyword).
- The view manipulation widgets have been reduced and some of them merged.
    - The animation buttons have been removed from the author collaboration view and the citation views. Users can stop the animation of the author view by zooming into the author view and start it by zooming out. In addition, the animation of the citation views automatically stops after the citation graph have been laid out. These changes have been made in order to comply with the need to reduce the physical activities associated with users' interaction with the interface and will be discussed in Section 7.6.2.
    - The citation buttons of both citation views have been merged, since the multiple views have been synchronized, this is discussed in Section 7.6.1. As a result of this, there was no need to have different set of citation widgets associated with the varying citation views. If the user requests to see the 'cites' relationship between publications then the 'cites' relationship will be represented as well in the author citation view this is due to the fact that all views have been synchronized.
- Additional text details views have been added to the second prototype (Figure 7.5 (c)). Details of this will be explained in Section 7.6.1.
- The publication nodes have been filled in to improve visibility.

These were the changes that were made to the appearance of the interface as a result of updating the functionality and design rationale of the tool which was based on the results of the usability study. These changes are categorized into three categories:

- The multiple view problems
- The manipulative activity problem
- The refinement of the secondary activities

7.6.1 Multiple views

In order to address the multiple views problem and the confusion that the users expressed in relating information in the various views the following was done:

- Synchronize the views
- Add additional details
- Make the collaboration and citation links interactive

Synchronize the views

The first step taken to address the multiple-view usability problem is to synchronize the views by relating all the views in order to correspond to the selected author, since the author is the starting point of the interaction process. Hence, if no author is selected then no details are displayed in all other views: publication and citation views. Once an author is unselected then all the other views are cleared, hence the elimination of the 'Clear' button. The reason for doing that is that it was observed that when users were interacting with a particular view they were not interested in what was displayed in the other views. By synchronizing the views all the information displayed in the various views will be related to the exploration task that the user is engaged with and hence it will be relevant to the task that the user is trying to accomplish. Unlike with the previous prototype where the information displayed in the various views could have been unrelated leading to the need for clearing each independently. This idea of synchronization was also applied to the citation views where the selected citation type (cites or cited-by) applies to both the publication citation view and the author citation views.

Add details in one view

Instead of the user having to look for information between views, details were added to the single views avoiding the need for the user to look for information in various views. The means with which this is done is listed below.

First, collaboration links were added in the author view. This was done due to the fact that users when they interacted with the author view found it difficult to visually distinguish between clusters of authors. According to Engelhardt (2002) object-to-object relations can be depicted by spatial clustering, linking, containment, or superimposition. Since the clustering used was not very clear to the users especially when there was an overlay of objects, as seen in Figure (7.6) the decision was to use linking in addition. This permitted the users to be able to visually distinguish groups of

collaborator authors upon request. As the user hovers over or clicks on an author node all collaborators of the node are visually distinguishable. The names of the selected author and his/her collaborators are visible. As seen in Figure 7.6 when the user selects an author her/his collaborators are visually distinguishable. In this example the user used the visibility scrollbar as a means of enhancing the visibility of selected author by fading out the visibility of the unselected authors.

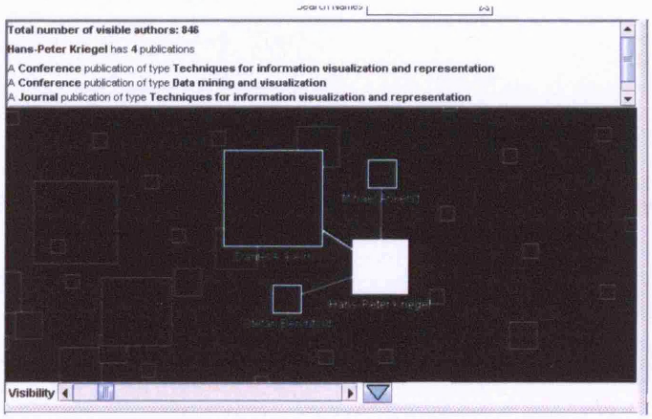


Figure 7.6 As the user clicks on the authors his/her collaborators become visible

Second, scrollable text detail windows were added on the top of the author view, as seen in Figure 7.6. As the user selected the authors a text description of the authors which includes the name of the author and the number of publications of the authors in addition to the type and research interest of each of his publications are displayed.

Same applies in the publication view (Figure 7.7). As the user clicks on a publication in the publications views, details of that publication are displayed in the text detail view of the publication details window. This lists the title of the publication, the authors of that publication, the reference string of that publication and the number of times it was cited.

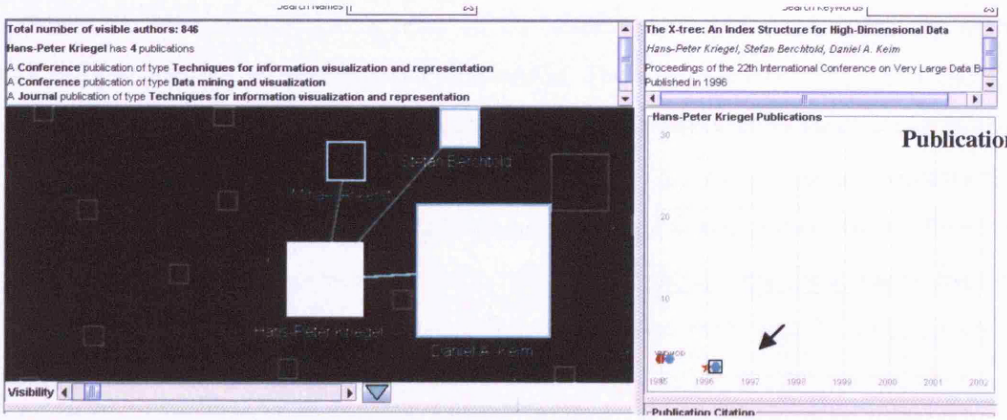


Figure 7.7 Publication details

The text details relate to the corresponding selected author or publication or their associated links. This was done due to the fact that users, as discussed in Section (7.5.1) forgot the meaning of the y-axis hence by adding the details window this might assist users in remembering the fact that the y-axis corresponds to the number of times that a paper was cited. Another potential modification could be to change the visual properties associated with the number of citations, whereby it could have been represented in terms of the size of the publication where size is a good visual cue to represent the visual quantity (Engelhardt, 2002).

Link interactivity: Similar information reached in different ways

In addition to adding the text details view the tool was made more interactive by making the links clickable as well as the nodes. This allows similar information to be reached depending on where the user is. If the user is in the author collaboration view and wants to identify the papers that two authors collaborated on, then the user simply clicks on the collaboration link in the author collaboration view.

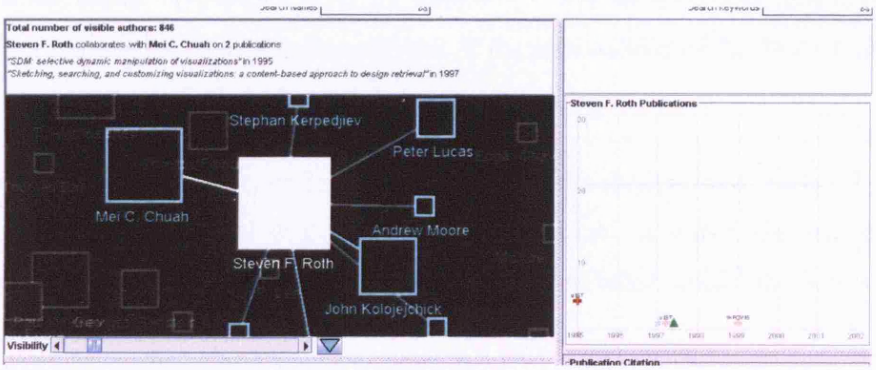


Figure 7.8 Publications that two authors have collaborated on

As seen in Figure 7.8 the user selects the collaboration link between "Roth" and "Chuah" as a result, details of this collaboration appears in the author detail view indicating the number and details of the publications on which they collaborated. The user can also get similar and additional information, such as the type of publication, by looking at the publication view where the paper that they collaborated on are emphasised visually by fading away the other papers. Similarly if the user is interacting with the publication view and would like to know the authors that collaborated on a paper then the user can either read in the publication's text detail view the name of the authors or click on the publication, as seen in Figure 7.7, where the user will be able to identify the collaborators in the author collaboration view.

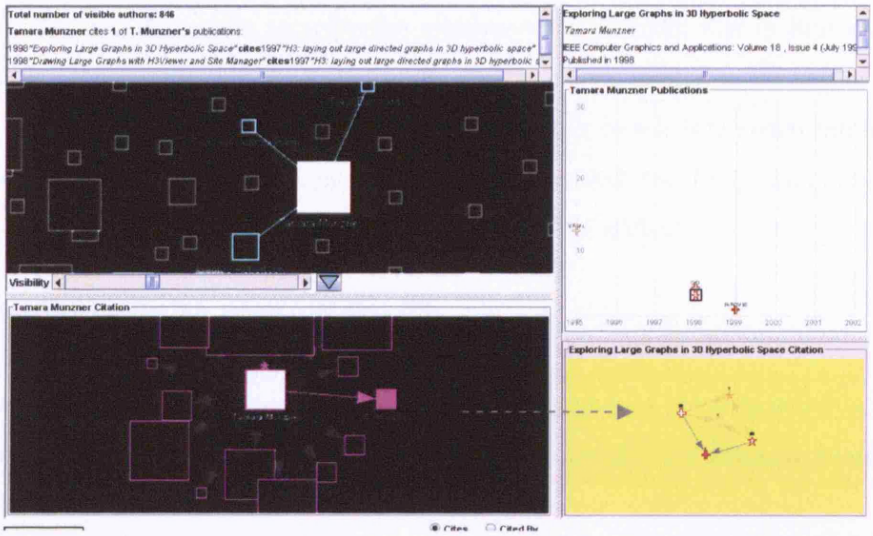


Figure 7.9 Details of the author citation relationship

If the user is interacting with the author citation view and the user would like to see the publications that make up this citation link then the user simply drags the author citation link into the publication citation view and hence will be able to see the details of this relationship. As seen in Figure 7.9 two publications of the selected source author cite one of the publications of the destination author. The user can also read details of this in the author detail window.

The user can reach the same information from the publication citation view. Figure 7.10 shows that if the user clicks on a citation link in the publication citation view then the user can see which authors in the author citation view make this relationship; in other words, the author can see who the authors of the target publication are.

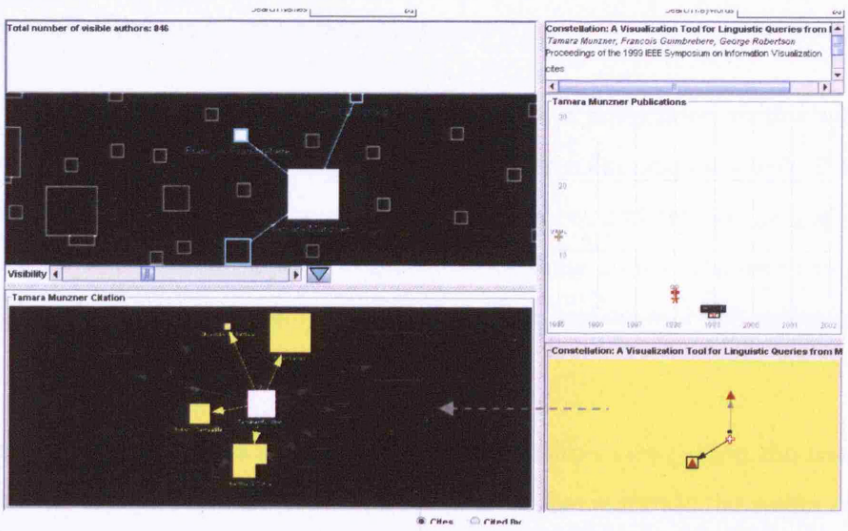


Figure 7.10 From the publication citation view to the author citation view

The design rationale applied in order to solve the multiple-view problem was to first synchronize the views by making the information displayed in the various views related to the exploratory task that the user is currently engaged with. Second, allowing the user to reach as much information as possible from the view in which they are engaged by: adding the text detail view and increasing the interactivity of the tool by making the links clickable as well as the nodes.

7.6.2 Physical activity reduction

Users during the study, as seen earlier, complained about the number of physical activities that they had to engage with in order to be able accomplish a task, specifically the constant zooming. This problem was addressed by adding an auto-zoom feature.

The view that the users were constantly zooming in and out of is the author collaboration view since it represents the main view that the users would have to use in order to navigate the domain. Users use this view to locate authors of interest. The auto-zoom feature that was added is activated by right clicking on the background of any of the 4 views: the author collaboration view, the publication view, the publication citation view, and the author citation view.

- The author collaboration view – when the user right clicks on the background of this view the tool automatically adjusts the view by bringing all the searched author results into focus.

- The publication view – when the user right clicks on the background of this view the tool automatically adjusts the view of the author collaboration graph by bringing the selected author into focus. The reason for that is that the publications that are displayed in the publication view are related to the selected author.

- The publication citation view – when the user selects a publication in this view then the authors of that publication are highlighted in the author collaboration graph. If the focus of the collaboration graph at that moment did not include these authors then instead of having to zoom out of the collaboration graph to visually locate these authors the user can simply right click on the background of the publication citation view and the tool will automatically zoom into those authors.

- The author citation view – as with the publication citation view, when the user selects an author in the author citation view and would like to see that author in the author collaboration

view then the user simply right clicks on the author citation view and the tool will automatically zoom into that author in the author collaboration view.

7.6.3 Refining the secondary activities

The secondary activities represent the manipulative activities that users engage with in order to support users in their exploration of the domain (Chapter 6). The design and layout of the tools were slightly redesigned in order to improve the usability of the tool and to support the needs of the experiential study which will be discussed in Chapter 8.

Filter

In the first prototype (Chapter 6) the user was able to filter the interface using the type and the research interest of authors and their associated publications. The queries that this filtering generated were OR queries. This was refined to allow for the user to either OR or AND the terms of the filtering query.

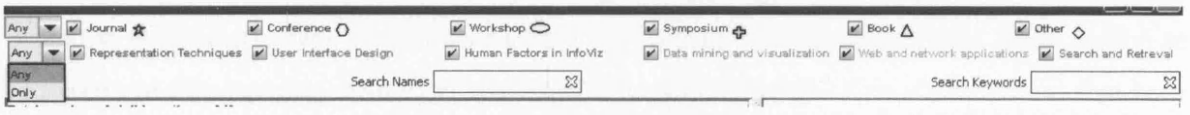


Figure 7.11 Filtering functions

As seen in Figure 7.11 the user decides whether they would like to AND the terms or OR the terms by selecting either "only" or "any" from the drop down list.

Search keywords and titles

In addition to the user being able to search for author names, a feature was added that allows the user to search the titles and the keywords of publications. This is essential as indicated by the qualitative requirement study discussed in Chapter 5. This feature was not added to the previous prototype as the tasks that were given to the users did not include keyword searches. However, since users were to be engaging in high-level activities in the next study it was essential to add such a feature.

Highlight searched nodes

In the previous prototype only author nodes were highlighted as a result of the search. A feature was added that caused the publications to be highlighted in correspondence.

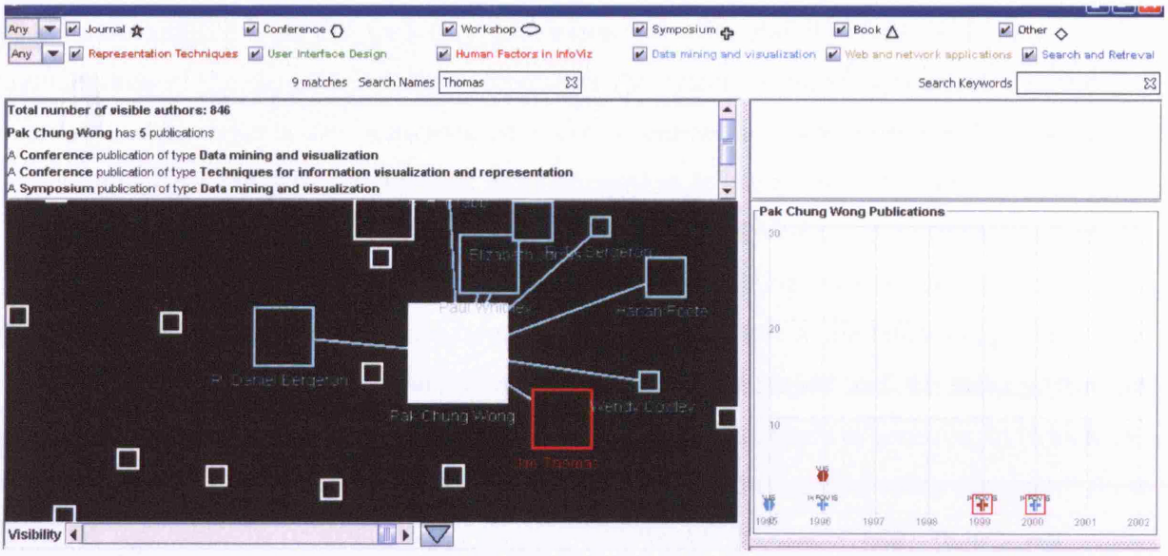


Figure 7.12 Highlighting an author and his corresponding publications as a result of a search activity

In Figure 7.12 the user selected "Pak Chung Wong" and searched for the name "Thomas". As can be seen in the figure "Jim Thomas" is highlighted in red in the author collaboration view and the papers that he published with "Pak Chung Wong" are highlighted in the publication view. Any displayed publication where the searched author is a co-author will be highlighted. Same applies to keyword and title searches. If the user searches for the word "design" then all the authors that have that word in their publications' titles or keywords are highlighted in addition to the displayed publications themselves.

7.7 Subjectivity: An Insight into User Experience

The study has given insight as to the reason for the lack of consensus when it comes to finding a methodology for the evaluation of InfoVis tools. This is related to the fact that the experience is highly subjective, so task-based approaches are unlikely to capture the motivations and purposes for using the system. Spence (2001) defines domain related visual representation as an externalization of the data. The externalization process is the role of the InfoVis designer, transforming the abstract domain concepts into visual representations. The complement of externalization is internalization, as externalization deals with the interface and internalization deals with users' internal knowledge. The internalization process is the main role of the InfoVis user. It results from users' interaction with the external representations. As a result, users start to make sense of the represented concepts and hence build internal models of the domain (Ware, 2004). There can be no right or wrong model – it is subjective and hence not susceptible to rigorous tests (Carroll & Olson, 1987).

When users interact with the tool they are interacting with the interface in addition to the externalization of the data. The interface represents the syntax of users' interaction, whereas the generated insight reflects the semantics of users' experiences. The interface is part of the interaction process and is well researched and addressed in HCI e.g. (Norman, 2002). It forms the basis of usability evaluations which target the gap between the system image and the user model. The controlled task-based usability study assisted in evaluating merely the syntax of the visualization tool and its associated interface. However, there is more to the InfoVis experience than just the visual syntax. It is all about the meanings that are conveyed and the feelings that are generated. The InfoVis user experience can be compared to a literacy experience, by which the correctness of the syntax does not necessary guarantee its ability to conveying meaning. As a result, the tool needs to be evaluated by tapping into the internalization process, in other words targeting the semantics of the experience. Merely a glimpse of these experiences has been obtained through the comments that the users gave and the observations the researcher captured during the study. For example one of the participants commented:

"It got easier to use with more practice, also became more adventurous..."

This comment can be related to the fact that the study revealed that users' performances improved with the complex tasks, and hence raises the question on whether or not performance improved because of practice or because of the unrestrictive nature of the task which allowed the user to tap into the semantics of the experience. Findings such as this leads to interesting questions that needs to be further explored such as: What makes it "*more adventurous*", what makes it a better experience? Quantitative methods are not designed to answer such questions; qualitative research methods would be more suitable as they are targeted towards answering such issues.

7.8 Conclusion

This chapter has presented the study that evaluated the usability of the ALD InfoVis tool's interface. As a result of this study the interface of the ALD InfoVis tool was redesigned. Looking back at the motivation of the study (Chapter 1), this study has evaluated the usability of the interface and its manipulative activities. However, it said nothing about the users' conceptualizations of the domain, i.e. interaction with the externalization. When executing the low-level tasks, users tend to concentrate on accomplishing the task at hand without looking beyond it into the goal space; one of the users commented: *"I liked the system but I was trying to complete tasks given – it might mean more if I used it for research and saw interesting relations in papers"*. The interface is merely a

façade, which is crucial to the experience; however it is not the final point. The next chapter presents the experiential study which targets the goal space by tapping into users' experiences.

8. Capturing Users' InfoVis Experiences

8.1 Introduction

The interface is a crucial component in users' InfoVis experiences as it is through the interface that users are able to accomplish their goals. As a result, a usability study was conducted and presented to evaluate the usability of the Academic Literature Domain (ALD) InfoVis tool's interface (Chapter 7). In addition the study pointed to the fact that there is more to users' InfoVis experiences than merely the interface. This is what this chapter aims to uncover. In this chapter, a qualitative study conducted with the aim of capturing users' InfoVis experiences is discussed. The approach taken by this study is exploratory which is not common in the study of InfoVis tools.

Interestingly it was identified that users' experiences whilst interacting with the InfoVis tool did not solely depend on the amount of insight gained. In fact, it was identified that the users' overall experiences were based on the harmony between users' interaction with the interface and their domain related sensemaking activities. Following the analysis of the data and the generation of the InfoVis experiential theory it was identified that this theory fitted within the context of the instrumental genesis approach (Rabardel and Bourmaud, 2003). This approach is a theoretical framework that is based on Activity Theory (AT). It provides an elaborated account of the integration of artefacts into the structure of human activity. As a result, it was decided to contextualize the experiential findings into this theoretical background. This contextualization gives strength to the findings of this study and leads to the argument that when designing InfoVis tools it is the instruments that need to be designed rather than the tool, where instruments are cognitive appropriations of the tool.

8.2 From Low-Level Tasks to High-Level Tasks

Kobsa (2001) compared three commercial InfoVis tools, with three different datasets: data from a web-based dating service, technical data of cars sold in 1970-82 and data on the concentration of heavy metals in Sweden in 1975, 1980 and 1985. The study took the form of a task-based usability study. The tasks were generated as part of a brainstorming activity and were dependent on whether or not they would occur naturally in the real-world. In this paper they argued that giving users

simple low-level tasks, such as searching for a specific entity, or performing counting tasks makes it easier to identify the usability issues by relating them back to the specific tasks. However, they argued that such tasks have an unclear ecological relevance. This was based on the fact that when it comes to InfoVis systems there is more than one path to execute a task. This perspective agrees with the discussion presented in the previous chapter, where the task-based usability study assisted us in evaluating the usability of interface and its associated visual syntax. However, it hindered users' experiences, that is, users were concentrating on executing the tasks but they felt trapped as they were not able to explore the domain in a natural subjective manner. As a result, it was decided to evaluate the ALD InfoVis tool through the use of non-restrictive tasks that would allow the users the freedom to explore the domain in a manner that is non-restrictive and natural.

One way to look at users' experiences is through long-term case studies, whereby users are given the freedom to interact with the tool in a natural manner based on their naturally occurring needs. These studies are quite rare in the InfoVis field due to the great effort that is associated with them. A recent example can be seen in a methodology devised by Shneiderman and Plaisant (2006). They present an evaluation methodology which they refer to as: Multi-dimensional In-depth Long-term Case studies (MILCs). The multi-dimensionality is related to the multiple usability data gathering methods used such as: interviews, surveys and automated user-loggings. The in-depth feature is related to the in-depth engagement of the researcher with the expert user in the working environment. Long-term is related to the length of these studies which can sometimes take several months, and last but not least the case studies aspect of the methodology is related to the detailed reporting that the researcher conducts on a small number of users in a realistic setting. We agree that longitudinal studies are ideal when it comes to evaluating InfoVis tools, since in such an environment users are allowed to interact with the tool in a natural non-restrictive manner. There is no better way to mimic a realistic environment than reality itself. However, long-term case studies are not always feasible due to time constraints or financial limitations. In addition, in most cases the results of these studies cannot be generalized, meaning that they are system specific and hence cannot be applied to the evaluation of other InfoVis tools.

To compensate for the realism of the interactive experience, Saraiya et al (2005) developed an evaluation methodology that aims at capturing users' insights through exploratory engagement with a visualization tool within a laboratory setting. The aim of that study was to evaluate five popular bioinformatics visualization tools. In order to create a realistic study design, no tasks were pre-devised. Instead users were asked to formulate questions that they would normally ask when faced with such a dataset. They then asked participants to interact with the tool until they felt that there

was no more insight to be gained. This evaluation method proved successful, as the authors reported. It allowed users to engage in exploratory tasks through which discovery and insight are achieved.

Due to the time and financial constraints associated with this research, a longitudinal study was impossible. As a result, Saraiya et al's evaluation protocol was employed whereby the intention was to ask the users to devise literature exploration tasks and to use the tool to execute such tasks. A pilot study was conducted with a second year PhD student. During the course of the study it was found that the student was confused by the task and indicated that he needed to have a target or a goal to work towards. This is believed to be related to the nature of the literature domain, whereby literature is only explored when the researcher has a specific goal or question to answer (Chapter 5). As a result, users were given a high-level task with a concise goal, as will be discussed in detail in the next section.

8.3 The Study

The study was based on giving the users a high-level task which required users to get familiarized with a specific concept. A total of 12 users participated in the study. The following is a detailed description of the aim and format of the study in addition to a detailed description of users and their background. It is crucial to understand users' backgrounds and knowledge in relation to the represented data as this will have an effect on the users' overall experiences.

8.3.1 Aim and objectives

User experience is a broad area of research within HCI as explained in Chapter 2; it includes the study of aesthetics (Mahlke & Thuring, 2007), beauty (Hassenzahl, 2005), fun (Blythe, 2004), pleasure (Jordan, 2000), and emotional design (Norman, 2004). By looking at user experience from these areas, it can be seen that users' experience within the context of InfoVis is related to the aesthetics of the representations, e.g. (Cawthon & Moere, 2007), due to users' reliance on the externalizations. The importance of aesthetics is not argued against; however it is believed that it is not the only factor that affects users' experience; for example, the effectiveness of the tool in communicating insight to the user is a crucial component. The constituents of users' InfoVis experience are unknown. As a result, the aim of the study revolves around generating a holistic understanding of users' experiences whilst interacting with the academic literature InfoVis tool. The objectives of this study can be summarized as follows:

- Conceptualize the relationship between the user and the InfoVis tool
- Determine the ability of the tool in assisting users in making sense of the domain

From these objectives it can be seen that there are no measurable components that could be relied on as part of this study. Going into the study, it is not known what to look for.

8.3.2 Study design

When it came to designing the study, it was determined that the best way to approach it was to rely on a qualitative research method. This is due to the fact that qualitative research methods are ideal for getting into users' thoughts, and that is exactly what is needed in order to satisfy the aim and objectives listed above. The study was designed in a manner that would allow users to interact with the tool in a non-restrictive manner which would allow them to engage in subjective experiences as it is these experiences that need to be captured.

The task

The ALD tool is a tool that represents literature data. It is designed with the goal of assisting users in familiarizing themselves with their literature and associated concepts. As a result, it was decided to give the users the task of familiarizing themselves with a specific concept, more specifically the Dynamic Queries (DQ) concept. This is due to the fact that the tool represents InfoVis literature and DQ is a concept within that field. The task was given to the users in the form of a scenario:

***Scenario**: At this point of your research you need to examine the concept of "Dynamic Queries" you do not know where to start. A colleague of yours has given you a paper reference as a good starting point: a paper written by Shneiderman in 1996 and is titled "Incremental ..." Your goal is to identify key researchers and publications that target this area and identify any commonalities or differences between these groups of people.*

From here it can be seen that the task does not specifically tell users what to do. It is high-level since it does not specify how the users are to interact with the tool. An exploration starting point was given to the users, by explicitly pointing to a paper that they could use in order to start their interaction processes. In addition, a few key pointers on the types of information that they needed to look for such as: identify key researchers and publications, and commonalities or differences between groups of people. This was stated as part of the task scenario (above), and is based on the requirements study conducted and discussed in Chapter 5.

Experiential data

In order to generate the experiential data needed for the analysis, observational and interview data were relied on. Observational data was based on the researcher's observations of the users interacting with the tool: i.e. their general behavior, the features of the interface that they were using or not using, any comments they gave during the interaction, etc. In addition, it was decided to record users' screen interaction with the tool just in case anything was missed during the study session. The interviews were designed in a manner that allowed users to talk about their experiences in general. Semi-structured interviews were relied on as in the requirement gathering study conducted in Chapter 5. This was due to the fact that at the time of the study design, the information that needed to be looked for was an unknown. The following are the basic questions that were relied on as part of the interviews; these evolved as the study went along:

- Explain the experience that you just had.
- How would you rate the experience that you just had? Was it positive, neutral, or negative?
- Were there specific incidents that you remember? Explain.
- How did you feel about your interaction with the tool?
- Was the tool able to give you insight?
- Can you compare your experiences interacting with this tool with your experience interacting with similar purpose literature tools?

Analysis

The approach that this research takes in understanding users' experiences is a phenomenological one, as explained in Chapter 2. Grounded Theory (GT) (Strauss & Corbin, 1998) is known for its power in understanding and unraveling phenomena as explained in Chapter 5. Hence, GT was relied on as the main analysis method. The study design took an interesting form, where it had the shape of a lab-based study with an exploratory nature.

8.3.3 Participants

The ALD InfoVis tool was designed to assist users in familiarizing themselves with a specific research area, hence targeting users of varying backgrounds. All users who participated in the study were proficient in using a computer. Most of them had a background in HCI, as can be seen in Table 8.1. As seen from the table, the participants had various backgrounds and experiences when it came to doing research. Most of them have had more than two years experience.

Users	Gender	Academic Status / profession	Research Experience	Knowledge in InfoVis			
				Concept	Tools	Literature	DQ
U1	M	Research Fellow in HCI	5 – 10 years	Yes	Yes	Average	Yes
U2	M	CS programmer	1 year	Yes	Yes	No	Yes
U3	M	1st year PhD in HCI	5 – 10 years	No	No	No	No
U4	F	Writing up PhD in HCI	3 – 5 years	Yes	Yes	Yes	Yes
U5	F	PhD Student in HCI	5 – 10 years	Yes	No	No	No
U6	F	Lecturer in HCI	5 – 10 years	Yes	No	Average	No
U7	M	Researcher, lecturer in HCI	5 – 10 years	Yes	No	No	No
U8	M	MSc in HCI	More than 10 years	Yes	Yes	No	Yes
U9	M	Working in industry (HCI-research)	2 – 3 years	Yes	Yes	No	Yes
U10	M	MSc in HCI	3 – 5 years	Yes	Yes	No	No
U11	F	Working in industry (Usability)	2 – 3 years	Yes	No	No	Yes
U12	F	Research Fellow – Crime Science	3 – 5 years	No	No	No	No

Table 8.1 Users' background information

In addition to demographic information, users were also asked about their background knowledge in relation to InfoVis. Questions were asked in relation to their understanding of the concept, their use of InfoVis tools in general, their knowledge of InfoVis literature and whether or not they have heard of the concept of Dynamic Queries (DQ). Most users knew what InfoVis was; half of them have interacted with InfoVis tools, whereas most of them did not have knowledge of InfoVis literature, see Table 8.1. Half of the participants indicated that they have heard of the concept of DQ; however, only two (U1 and U9) were able to identify seminal authors of such a concept prior to interacting with the tool. This indicates that most of the participants were novices when it came to the literature of the domain and the concept that they were exploring. Hence, they fitted the targeted audience. The table also shows that most users were experts in usability except U12 who was a research fellow in Crime Science.

8.3.4 Material

The study was conducted in a lab based environment, where the user was sitting in front of a computer (Dell XPS710, 2.40 GHz, 2.00 GB RAM). The screen recording software that we used

was ZD Soft Screen Recorder. The interviews were recorded using an Olympus (VN-2100PC) digital voice recorder.

8.3.5 Procedure

The researcher was present in the room observing the users and making notes of these observations. All users' interaction with the interface was screen recorded. Users, however, were not videotaped as the aim of the study was to capture users' interaction with the tool and not their gestures or body language.

The study was divided into five consecutive parts:

1. Demographic gathering session – users were given a questionnaire to fill-in in relation to their background information: more specifically in relation to their academic literature experiences and information visualization experiences, since such knowledge might have an effect on the experiences they have in addition to the insight that they gain.
2. System details – the researcher gave the users a detailed explanation of the system which incorporated an explanation of the interface and its associated functionality in addition to the visual representation.
3. Training session – users were given some tasks which they needed to execute in order to gain a better understanding of the interface.
4. The interactive session – users were then given the high-level task and were asked to interact with the tool until they felt that enough insight has been generated.
5. The interview – following the interactive session the users were interviewed with regards to the experience that they had interacting with the tool.

The forms used in parts 1 and 2 of the study can be found in Appendix C. The following is a detailed description of parts 3, 4 and 5 of the study.

Training session

The goal of the training session was to train the users in using the interface functionalities in addition to understanding the syntax of the externalization. This relied mainly on reusing primitive and intermediate tasks from the study discussed in Chapter 7 as their validity in testing the usability of the interface was established. A total of 10 representative tasks were given to the users. Complex tasks did not take part in the training session as they basically relied on the execution of a number of primitive and intermediate tasks. In addition, these tasks are considered as high-level tasks. Hence,

they would require reasoning and sensemaking activities which did not fit with the timeframe of the study. The researcher assisted the users if help was needed. The list of tasks given to the users can be found in Appendix C.

The Study: Interactive and interview session

The users were asked to use the visualization tool in order to execute the high-level task and to stop whenever they felt that they had generated enough insight. The users were not asked to perform a think-aloud (Ericsson & Simon, 1993). This protocol is generally used when it comes evaluating the thought process of problem solving and decision making by giving users a specific task; this did not fit with the aim nor design of this study, and hence was not relied on. The researcher explicitly indicated to the users that they were able to ask her questions if they wanted to be reminded of any of the functionalities of the tool, as the researcher was aware of the amount of functionality provided by the tool and that it could be difficult for the users to remember them all. In addition, the researcher did not want the users to be struggling with remembering the various functionalities; in fact she wanted them to concentrate on the task at hand. Only one user asked the researcher to be reminded of a function during the interactive session, whereas all the other users had no trouble remembering and operating the interface.

Following users' interaction with the interface, the users were interviewed by the researcher. The interview took the form of a semi-structured interviewing method .The entire session took a maximum of 75 minutes including form filling, training, interacting with the interface and participating in the interview.

8.4 Analysis

The interviews, researcher's observations and screen recordings represented the data around which the qualitative evaluation was conducted. The evaluation was based on GT. An overview of the GT methodology was given in Chapter 5. A total of 12 users took part in the study. This number was not predetermined however it depended on the reach of a saturation point. Five studies were conducted first and analyzed. The result of this analysis determined and shaped the following set of interviews with four users. The same process took place and finally the study was conducted with three users, when it was felt a saturation point was reached. In order to present the analysis of the qualitative study, a similar presentation scheme to the one followed in Chapter 5 followed, whereby the discussion started with a presentation of the overall theory and its main categories and concepts.

Following that each of the categories was explained in detail. This was done in order to facilitate the understanding of the analysis.

8.4.1 Theory of InfoVis experience: A harmonious flow

Users when interacting with InfoVis tools manipulate the interface in order to gain knowledge of the represented domain. This is done through users' engagement with a set of activities which are categorized into manipulative activities and sensemaking activities. Manipulative activities are the activities that the users engage with in order to manipulate the interface and its associated visual representation. Sensemaking activities are activities that users engage with in order to satisfy their intended goals, which might range from identifying a key paper to generating an overview of a research concept's evolution. These sensemaking activities are part of users' internalizations of the world which incorporates past knowledge and experiences. It is these internalizations that affect the personal strategies that users adopt in order to make sense of the represented domain. In order for users to have positive experiences both users' interface related activities and internalization activities needs to take part in a "harmonious flow" of interaction. Harmonious flow is the key concept around which the theory revolves, as seen in Figure 8.1.

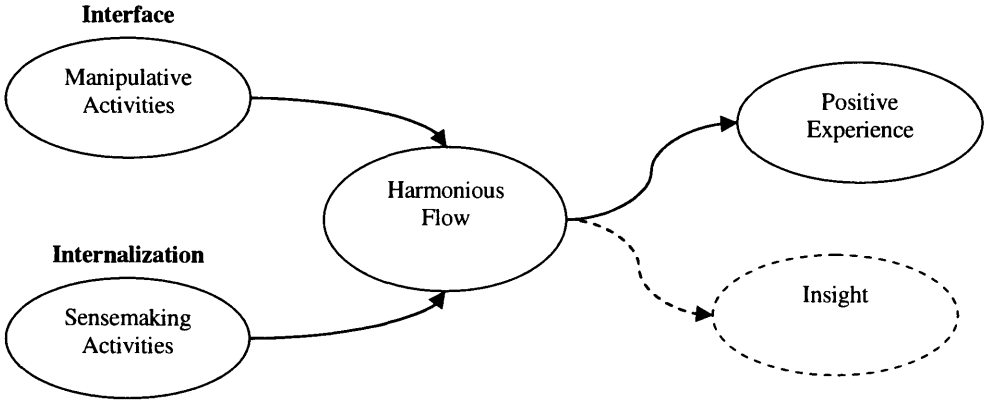


Figure 8.1 The InfoVis experience: A harmony of Interaction

A harmonious flow is achieved when the user is able to engage in an internalization process without interference. It is the harmony of interaction between the interface related activities and the internalization activities determines the type of experience that the user will have, as will be explained in detail in sections (8.4.5, 8.4.6, 8.4.7) . Insight is an output of users' interaction with the interface resulting mainly from the internalization process. All users that interacted with the tool were able to generate insight. However, insight on its own is not representative of a positive user experience. This is why it appears visually distinguishable from the other concepts. Users may gain

insight and yet have a negative experience. It is the overall experience that counts if we want InfoVis tools to reach the user and not merely the expert.

8.4.2 The interface

The interface is an essential component of the interaction flow. It is through users' interaction with the interface that insight and feelings are generated, and hence an experience arises. When users were asked to reflect on their interaction with the tool, they usually referred to either the functionalities or the data externalization. The externalization represents the visual representations that overlay the data: it is basically what the user sees (Spence, 2001). To make this distinction clear, when these users were asked to elaborate on their interaction with the tool they said:

> *U5: "I kept forgetting that **there was a button** to drop the one from there to down below"* – the user is referring to the functionality
>
> *U4: "I do like the fact that it represents **these clusters of information** cause you can see which authors are clustered together that is kind of nice."* – The user is referring to the externalization
>
> *U8: "If I had done that [marking publications] initially I wouldn't have had to keep **clicking on** each one to mark them I wanted to get a grasp of who was actually being involved and then I wanted to be able and **go though each of those and understand who they relate to** and that would have been a much quicker way to grasp the overall summary."* – The user is referring to both the functionality and the externalization of the tool.

From the users' perspectives, as seen from these examples, users' interaction with the interface is divided into two activities, the visual and the physical activities. The visual activities reflect the perceptual activities with which the users perceive and interpret the externalization. They are a crucial part in users' sensemaking activities as users rely on them in order to make sense of the represented domain. The physical activities represent the physical activities that users engage with in order to manipulate the interface, for example physically dragging the mouse and clicking on an onscreen button.

The ways in which users were talking about the visual activities and the physical activities and their associated relationship fitted within the context of Norman's seven stages of action (Chapter 2) and seen in Figure 8.2. The visual activities are part of the evaluation cycle, whereas the physical activities are part of the execution cycle. When the user engages in the execution cycle the visual externalization of the data is affected and changed. The user perceives and evaluates the changes

through engaging with a set of visual activities and the cycle goes on until the user's goal is achieved.

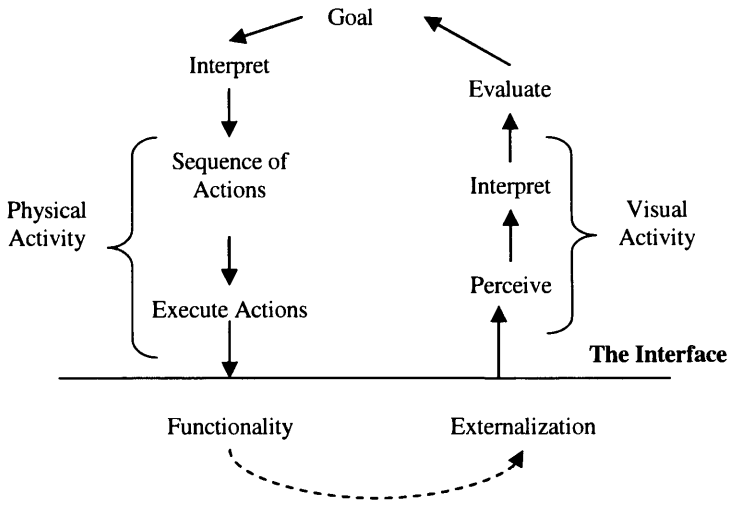


Figure 8.2 Visual and physical activities within Norman's seven stages of action

The analysis of the data has shown that in order to achieve a positive experience, one of the conditions is that there needs to be a harmony of interaction between the visual and the physical activities, whereby the physical activities should not interfere with users' visual activities. The following examples extracted from our interview data express this relationship clearly:

First, U3 expressed this relationship quite clearly, when talking about the interaction:

> *"the only thing that was kind of frustrating was having to zoom in and out all the time. Um cause especially if you are trying to go in between clusters of people ...**It depended on what I was trying to do**, if it was a natural break in between things...it wasn't [distracting] but if I was zoomed in say [author_1] and I want to go and take a look at [author_2] I got to zoom all the way out, then zoom back in, so yeah that was a little distracting".*

From here it can be seen that the user is indicating that the physical activities should not interfere with the visual sensemaking activities, and if they did then this would generate negative feelings such as frustration which might have an effect on the experience as a whole.

Second, user U2 said:

> *"I didn't want to do that **extra step of right clicking** I wanted to have a view to show me the summary of the document".*

In this example the user is talking about the physical activity of right-clicking and selecting the 'details' option from a popup menu in order to get to the details of a particular paper. He is explicitly saying that having to engage with this physical activity is not desirable as the details of a paper is an essential part of his sensemaking process and should be accessed in a more direct fashion rather than having to go through the right-clicking and selecting from a menu. This relates to a similar fact whereby the physical activity is breaking the flow of interaction of the visual activity.

Third, another user similarly commented, U10:

> *"It **[right clicking] was an unnecessary step**, the thing that I thought to be prominent first would be the information, that is the thing I need to get to first I didn't want to do all this filtering and all this stuff to get to the information".*

From here it can be seen that both the visual and the physical activities take part in users' InfoVis experiences. Hence, both should be taken into account when designing InfoVis tools.

8.4.3 Internalization process

Vygotsky (1978) describes the internalization process as the internal reconstruction of an external operator, where an operation that initially represents an external operation is reconstructed and starts to occur internally. The internalization results from the transformation from an interpersonal process into an intrapersonal one. An interpersonal process reflects interaction at the social level, whereas the intrapersonal reflects the individual level *"Every function in the child's cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological), this applies equally to voluntary attention, to logical memory, and to the formation of concepts"* (pp. 57). Vygotsky here describes the internalization process as a process through which social interaction becomes part of a child's life.

Within the context of users' InfoVis experiences, internalization is used to describe the process that the user engages with in order to understand the represented domain by relying on past knowledge and experience. One of the outcomes of the internalization process is the identification of a strategy that is natural to them. This process involves the user's interaction with the externalization of the data through executing a set of visual activities. The internalization process is the process that occurs in the users' mind. It is subjective and hence differs from person to person. It is mainly affected by the way with which the users make sense of the domain.

The effect that the internalization process has on users' InfoVis experience, as has been identified from the analysis, is dependent on the ability of the user in using the externalization of the data in order to identify a personal strategy. In the context of the ALD InfoVis tool, the personal strategy is dependent on users' past experiences with the ALD. Users in this study were given a task where they were asked to familiarize themselves with the concept of DQ, and its various research camps. In order to accomplish this high-level task the users engaged with a set of low-level tasks such as: looking for prominent authors, identifying key publications, looking for various research areas, etc. It is through the execution of these lower-level tasks that the users were able to achieve the higher-level goal through the generation of knowledge and insight across the interactive exploratory experience. Getting acquainted with a research concept through the exploration of various literature variables is quite familiar to all academics. Hence, users relied on their background experiences in addition to their understanding of the tool's design and functionality which resulted from the training session in order to devise these strategies. These strategies are personal and hence differ from one user to another, e.g. U2 explained his strategy as:

> *"I tried to identify firstly key people and then maybe key concepts within the concept of DQ I was trying to search for. And then tried to find papers afterwards that was the thing to try and get and overview first and then try and narrow down to specific documents, so authors then concepts then documents"*

Whereas, U8 described his as:

> *"I wanted to get a grasp of who was actually being involved and then I wanted to be able, and go through each of those and understand who they relate to and that would have been a much quicker way to grasp the overall summary"*

In addition to the strategy differing from one user to the next, the strategy that the user employs may differ for the same user, depending on the task, the goal and the user's knowledge. An example that supports this from the data is the following:

> *U1: "So it is interesting that you gave me that initial paper as a starting point, if I followed the strategy that it suggests which is to span out from that paper I might have used the tool in a very different way".*

The user in this example is commenting that if he had started the exploration process using the paper given to him by the task sheet then he would have employed a different strategy. This shows that the strategies employed by the users may even differ for the same person depending on the task at hand. As the users interact with the tool the strategies may change as they start to gain insight and knowledge, e.g. U3 said:

> *"at first before I remembered about the whole abstract thing I was kind of trying well ok I can see how people connect but I was thinking well but I am not really learning very much about [the concepts] ... apart from you know kind of ok what categories they fit under and generally what people were doing with it".*

From here it can be seen that the ability of the users to identify a strategy has a direct effect on users' overall experiences. This depends mainly on the design of the externalization and its associated functionalities.

8.4.4 Harmony of interaction and the user experience

The harmony of interaction is what is claimed to lead to users' InfoVis experiences. This harmony is dependent on the relationship between users' manipulative activities (interface) and the sensemaking activities (internalization). In order to better understand this relationship, users' experiences are categorized into three categories: positive, negative and neutral. This categorization was based on commonalities that have been found between the different groups of users. It is important to note that this categorization is based on the analysis of the data and is not an attempt to quantify experience.

Some users were asked to explicitly rate their experiences (U6 to U12). However, their personal rating was not used as the basis of the categorization as this might have been biased by the fact that the users were aware that the researcher is the developer of the tool, and hence users might have been intimidated in rating their experience if it was negative, and from the other extreme, some users might have enjoyed the novelty of the experience and hence rated it as being positive. The reason some users (U6 to U12) were asked to rate their own experiences was not for the sake of experience rating per se, as this is not the goal, but it was done in order to assist in the confirmation of the experiential categories and concepts that were emerging from the analysis. This was reflected by the reasons that the users were giving for such ratings. This assisted in the general analysis of users' InfoVis experiences.

It is important to note that this categorization was not based on quantitative data, such as users' interaction time, speed of generating insight, or the depth of the insight. However, it was based on pure qualitative data analysis reinforced by the researchers' observations of users' interaction. The categorization depended mainly on:

- Their ability in identifying and expressing a personal strategy
- The relationship between the visual and the physical activities
- General attitudes they were having towards the tool: whether it was positive or negative

Table 8.2 shows that five of the users were rated as having had positive experiences, three were rated as having a negative experience and four were rates as having a neutral experience.

Users	Overall Experience
U1	Positive experience
U3	Positive experience
U6	Positive experience
U8	Positive experience
U9	Positive experience
U4	Negative experience
U10	Negative experience
U11	Negative experience
U2	Neutral experience
U5	Neutral experience
U7	Neutral experience
U12	Neutral experience

Table 8.2 Users' overall experiences

8.4.5 Positive experience

Users that were rated as having a positive experience were those that:

- Were able to identify a personal strategy
- Explicitly talked about the internalizations process with little reference to the interface
- Generally had positive attitudes towards the tool

All users that were rated as having positive experience fitted the described profile. In this discussion the quotations taken from U1 and U8 will be referred to in order to show the consistency in the categorization scheme across users. U1 was not asked to explicitly rate his experience, whereas U8 was. U8 rated his experience as being positive and the analysis of the data supported that.

Personal strategy

Users that were rated as having positive experiences were able to easily identify a personal strategy. By mere observation, it was clear that these users were not struggling with the interface and its related functionality. Instead, they seemed confident. Users had clear goals that they were working towards achieving. When asked to talk about the experience that they had with the tool they tended to explain such an experience in relation to the ability of the tool in assisting them to execute their own strategies. For example, U1 started to explain the experience that he had with the tool by referring to the ability of the tool in assisting him to generate a personal strategy:

> *"this [the author representation] representation was key for me... and it sort of gave me a sort of general sense of geography of the task and* ***allowed me to be****, what I thought to be* ***relatively systematic****".*

Similarly, U8 said:

> *"I wanted to get a grasp of who was actually being involved and then I wanted to be able and go through each of those and understand who they relate to and that would have been a much quicker way to grasp the overall summary".*

Internalization vs. Interface

From the analysis it was observed that users that were rated as having positive experiences mainly talked about the ability of the tool in assisting them in the internalization process. Interestingly they rarely referred to the interface and its associated physical activities. In other words these users were mostly elaborating on the power of the visualization in reflecting meaning. To illustrate this clearly, during the interviews users were asked to elaborate on any incidents that they remembered as part of this interactive experience. The following are examples:

> *U1: "being able to go through them and* ***put my own****, so its like a two step filter so the system filters and then I filter".*

> *U8: "I remembered that you could mark all the associated authors which is a really handy little thing if you want to* ***get a grips with much of the overview much more quickly****".*

From here it can be seen that the incident that the users mostly remembered were related to the ability of the tool in assisting them in expressing and generating meaning. For example, the overviews that the users were able to generate subsequently assisted them in gaining insight and knowledge of the domain. Comments similar to these have been consistent throughout the interviews which relate to the users that fit into the positive experience category. Interestingly, the incidents that these users remembered did not include comments that relate to the usability of the tool, as will be seen when talking about users with negative experiences.

Positive attitudes

Users that were rated as having a positive experience, in addition to identifying a personal strategy, seemed to have generated positive attitudes toward the tool. These were generally related to the ability of the tool in satisfying their expectations when it came to interacting with the tool and the ability of the tool in assisting them to reach the information they need. The following are examples:

> *U1: "a lot of my intuitions were* ***satisfied****".*

> *U8: "I got the data that I wanted um so I don't think it affected me ...The tool can very quickly give you text based information and shape based information rather than just color based information. It seemed to, so* ***I was not upset.****"*

It is important to note that U8 is color blind and hence it was essential to identify whether the visual cues used by the tool would be able to satisfy his expectations and needs.

Generally, the users that were categorized as having had a positive experience were very enthusiastic when talking about their experiences interacting with the tool. Some of these users were very enthusiastic about the tool due to its ability in satisfying a particular problem that they were facing as part of their past experiences. In other words they were visualizing the tool as part of their daily activities. U9 and U8 expressed this very clearly:

> *U9: "I would say very positive experience as I said I like it a lot and* ***I would love to see it out in the market*** *I would want to use it because, you also have to know as I am a practitioner and I am kind of disconnected from the field, even basic things you do not have very much time to follow".*

> *U8: "this tool is really helpful for those coming into lots of new areas or if you are doing work based upon so many different subject groups* ***as I am about to*** *you are going to need a tool just like this to get to grips with how many different areas and how many different people, papers you are going to be able to gather in any one context".*

From here it can be seen that, for users that seemed to have positive experience, the interface was merely a mediator that assisted them in their sensemaking activities; it was not what they were concentrating on. In fact, their experiences were mainly reflected as part of the internalization process. Somehow they did not seem to be seeing the interface as they were concentrating on their internalization of the domain, going beyond vision and into perception.

8.4.6 Negative experience

Users that fit into the negative experience category are users that encountered problems whilst interacting with the tool. These problems, in certain cases, were related to usability; however most were due to the ability of the tool to assist the users in their sensemaking activity. In other words, the externalization of the data did not fit with their past experiences in making sense of their literature domain. As a result, there was a problem in the ability of the tool to portray any advantages over the literature sensemaking tools that these users were already using, which were generally search engines and digital libraries such as Google and ACM. In order to better understand this categorization of users, the following is a detailed discussion of the experiences that these users had from the perspectives of the three identified properties: personal strategy,

internalization vs. interface, and general attitude. Quotations from users U4 and U10 will be used. U4 was chosen due to the strong views that she had and the expressiveness of her comments. U10 was chosen due to the fact that this user rated himself as having a neutral experience where in fact he fitted the negative experience categorization.

Personal strategy

The analysis and observations have shown that users who fitted in the negative experience category were rigorously interacting with the visualization, exploring a lot of its features and trying to understand its design rationale. However, the difference from the users of positive experiences was that these users were trying to adjust their personal strategies in accordance with the tool's design. They did not seem as if they were moving forward in executing the overall goal. This indicated that the sensemaking process was not very natural to them. U10 commented:

> *"I am treating this as a visualization of papers rather than a visualization of authors"*

This user was constantly being confused by the visual representation whereby he was treating the main window as a representation of publications rather than a representation of authors, he commented:

> *"author relationships I think are probably secondary"*

From here it can be seen that the design rationale adopted by the tool did not meet the users' expectations, and hence did not assist the user in making sense of the domain. U4, on the other hand, was able to make sense of the domain through the identification of a personal strategy, however the personal strategy adopted by this user did not rely on the visual features provided by the visualization; in fact, it relied on the user looking for keywords, identifying papers and reading the abstract. When the user was asked to comment on her experience she said:

> *"I am not sure if the visualization tool actually helped"*

When she was asked to comment about the means with which she made sense of the domain she said:

> *"just you sort of just see the abstract and you are like ok well this fits into this general category whereas this fits into this other general category".*

Hence, she was relying on the textual data and not on the externalization. Users that fit into this category tried to identify a personal strategy; however, the tool did not assist them in identifying a strategy that they were comfortable in pursuing. This is reinforced by the following comments:

> *U4: "I am more used to the regular search engine so this is interesting and it is pretty um but I am just used to the other one"*
>
> *U10: "I probably want to use the techniques that I use normally rather than change to a different tool. I mean there will have to be big prominence to need to change to a different tool"*

These users, like all users that fit into this category, did not feel that the tool was able to provide them with any advantages, so they did not seem to be enthusiastic about the experiences that the tool provided.

Internalization vs. interface

Users that fitted into this category were not able to go beyond the interface. They did not really engage in a sensemaking activity as they were unable to identify a personal strategy. When these users were asked to reflect on the experiences that they had, they merely pointed to features of the interface as seen in the following examples:

> *U4: "I was frustrated because I kept on wanting to **drag** and it won't drag"*
>
> *U10: "I had to **right click** on it cause I had to do that all the time and that was a bit annoying."*

These users mainly talked about the interface related physical activities and rarely referred to the sensemaking activities. The experience that they remembered was related to the syntax of the tool rather than the semantics. It is believed that this can be a strong criterion which could assist in categorizing the experiences that users are having. Hence, determining whether or not a user have had a positive experience relies on the ability of the user to see beyond the syntax and into the semantics by migrating the user from the interface into the internalization process whereby the tool, as an artifact, would seem invisible and the user would merely see the domain related internal models created as part of the internalization.

Negative attitudes

The negative attitudes that these users generated as a result of interacting with the tool were generally related to the inability of the tool to fulfill their expectations. Looking at the examples

discussed earlier it can be seen that words like *frustrating* and *annoying* were used. It is true that these comments seem to be related to the physical activities that are associated with executing a specific activity. However, looking at it deeper and relying on the researcher's observations and screen recordings analysis, it has been identified that these users are frustrated for the mere reason that they are unable to reach the information that they need in a straightforward manner. The following are a few more examples:

U10 was complaining because he wanted to be able to get to the textual information in a manner that was faster than the one provided by the tool, whereby the user must right click on the publication and select the "details" option from the popup menu. To this user, and also users U4 and U11, the crucial parts of providing a good experience were missing from the tool. This relates to the incompatibility between the design rationale and their internalizations of the ALD experience. To better describe this, the following is a quotation taken from U11 who, when asked to explain the experience that she just had, said:

> *"For some reason I don't know why it is sort of narrowing towards the side of negative. I guess cause I feel that there is a lot,* ***it is almost there****. There is all this information like I can tell ...immediately I can see what is important, but then when you start actually manipulating bits of it feels like* ***it doesn't give me enough I don't know why!****"*

Negative experiences arise as a result of the tool's inability to assist users in identifying a personal strategy. As a result, they are unable to bridge the gap between the functionality of the tool and the domain's externalization.

8.4.7 Neutral experience

Last but not least, users that do not really fit within the positive or the negative experience categories were rated as having neutral experiences. As will be seen from the examples presented, there is no consistency between these: whether it is related to the interface, the internalization process or the general attitude. However, it was interesting to see that the majority of these users were able to make sense of the externalization through the identification of a personal strategy. The exception to this was U5 who was not motivated in performing the task due to her lack of knowledge of the InfoVis literature that was represented by the tool. When this user was asked whether or not the tool was able to give her insight she said:

> *"I think so, it is not really my field so it was a little bit more difficult and I think if it was something obviously more related to me then yeah I would be. It would be very nice to follow all those links easily".*

What distinguishes these users from other users is the novelty factor, where they have all mentioned the novelty of the experience and made it an explicit part of their interview. This was very clearly expressed by user U7: when he was asked to rate the experience that he had, he said:

> *"I would say neutral because ... I think that I found, in theory, what I was looking for, wanting to know who the main authors were in the field and where the main sources of literature would be and I found that quite quickly really in that sense it was positive, but the actual use of the tool that looked quite complicated was more on the negative side so I think that overall it would be neutral."*

To describe this categorization in more detail, quotation from users U2 and U12 interviews will be used throughout the discussion. U2 was not asked to rate his experience; however, it was determined that he fits into this category, as will be seen next. The same applies for U12 even though this user, when asked to rate her experience, rated it as being positive. However, it was apparent that the reason she did so was due to the novelty of the experience as can be seen from this comment:

> *"I think it is positive because it gives you* ***a new way of looking at it, and I have never had that*** *before so that is interesting"*

The following is a detailed description of what makes a user have a neutral experience from the perspective of: personal strategy, internalization vs. interface and general attitude.

Personal strategy

All users in this category were able to identify personal strategies. From observations, U2 was easily able to relate his personal strategy with the one adopted by the design rationale of the tool's externalization and its associated functionality. This can be seen from the comment that this user gave. When asked to talk about the strategy that he adopted in executing the task he said:

> *"I tried to identify* ***firstly key people*** *and then maybe* ***key concepts*** *within the concept of DQ I was trying to search for. And then tried to find* ***papers afterwards*** *that was the thing to try and get and overview first and the try and narrow down to specific documents, so authors then concepts then documents."*

Looking closely we can identify that this strategy is the exact strategy that was adopted by the tool's design rationale. Similarly, user U12 commented:

> *" is kind of ... of straightforward to use, you just explained it to me and you know, and even new things that you were saying make sense because you do something similar in the same way and so on."*

From the analysis of the observational notes and the screen recordings it can clearly be said that users that fit into this category are similar to users that fit into the positive experience category when it comes to the personal strategy.

Internalization vs. Interface

Users that were categorized as having neutral experiences seemed to be taken by the novelty of the experience more than the ability of the tool to add to their internalized knowledge. They were mostly fascinated by the externalization which is part of the interface. When asked to elaborate on what they remembered out of their interactive experience they said the following:

> *U2: I think the big thing I'll take with me is looking at collaborations* ***it is not something that I ever looked at or taken seriously*** *or used in my search in the past I don't normally look at who collaborates with who as a factor so it is something I'll take more notice of now that I have seen it"*

> *U12: "probably the networking bit, because* ***I have never seen anything like that****"*

Externalization is the core of the sensemaking process; however, based on the analysis of these users' interviews it not clear whether these users would be able to see beyond the externalization by tapping into internalization.

Neutral attitudes

There seemed to have been a conditional factor associated with the attitudes that these users were generating as a result of their interaction with the tool, where users generally indicated that the experience was positive "if ..." this or that was available. For example, a user indicated that she was having a good experience however she did not seem to be motivated due to the domain of interest, as seen previously in the comment given by U5. On the other hand, another user indicated that she was having a positive experience due to the efficiency of a specific feature. For example user U12, when asked if this tool was able to give her insight, said:

> *"If we had an improved version"*

Whereby she was pointing to the primitiveness of the search feature. Similarly, U2 commented:

> *"I wanted to scan more and I could scan more text"*

From here it can be seen that no assertion can be made as to whether or not these users were having a positive experience. By mere observation, these users could have been categorized as fitting into

the positive experience category. However, with detailed analysis of their interview data it is clear that their enthusiasm is related to the novelty of the experience. Hence, once the novelty factor wears off the experience might go in the direction of positive or negative.

8.4.8 Insight

Insight gain is the goal of users' interaction with InfoVis tools as Card et al (1999) states *"the purpose of InfoVis is insight not pictures"* (p. 6). However, before starting this discussion it is important to explicitly state the fact that there has not yet been an agreed upon definition of insight within the context of InfoVis literature. Saraiya et al (2005) conducted insight-based evaluation studies within the domain of biology (as discussed in Section 8.2), and they defined insight as *"an individual observation about the data by the participant, a unit of discovery"* (p. 444). North (2006), on the other hand, acknowledges the fact that defining insight is a challenging matter and hence does not attempt to define it but instead characterizes it. He describes four characteristics of insight which are (p.6):

- Complex – insight is complex, involving all or large amounts of the given data in a synergistic way, not simply data values
- Deep – insight builds up over time, accumulating and building on itself to create depth. Insight generates further questions and, hence, further insight.
- Qualitative – insight is not exact, can be uncertain and subjective, and can have multiple levels of resolution.
- Unexpected – insight is often unpredictable, serendipitous, and creative.
- Relevant – insight is deeply embedded in the data domain, and connecting the data to existing domain knowledge and giving it relevant meaning. It goes beyond dry data analysis, to relevant domain impact.

As can be seen here, insight is a complex and subjective matter that accumulates with time. Based on this in addition to the study conducted in this chapter it is argued that insight cannot be solely relied on, as insight is complex and is dependent on many factors. As a result, insight was not explicitly measured as it is difficult to empirically affirm the amount of insight that each individual was able to acquire as part of their interactive experiences.

During the course of the study users were explicitly asked to elaborate on whether or not the tool was able to assist them in generating insight. For the purpose of this discussion insight from this point forward will refer to the knowledge that the users were able to discover as a result of their

interaction with the tool, whether it being as simple as identifying a key publication or as complex as generating a conceptualization or an overview of the concept of DQ. Determining such information helped in furthering the analysis of users' InfoVis experiences. The study has shown that all users were able to generate insight of the domain and yet not all of them had positive experiences. Table 8.3 gives a detailed description of users' backgrounds and knowledge in relation to the concept of InfoVis, its associated academic literature, and the concept of DQ. The aim of the table is to demonstrate whether there is an association between such knowledge and users' overall experiences. This table shows that all users were able to generate insight; however this insight varied from:

- Insight that is related to the identification of key authors and publications
- Insight that is related to the ability of the user to explicitly state knowledge that goes beyond the mere identification of key papers and authors, such as identifying the varying research areas associated with the concept of DQ or identifying the varying research camps associated with that concept.

Users	InfoVis Background Knowledge				Insight	Overall Experience
	Concept	Tools	Literature	DQ		
U1	Yes	Yes	Average	Yes	Deep insight (clusters of research areas)	Positive
U3	No	No	No	No	Deep insight (research areas)	Positive
U6	Yes	No	Average	No	Few key authors	Positive
U8	Yes	Yes	No	Yes	Deep insight (author clusters)	Positive
U9	Yes	Yes	No	Yes	Deep insight (clusters)	Positive
U4	Yes	Yes	Yes	Yes	Deep insight (research camps)	Negative
U10	Yes	Yes	No	No	A few key authors and publications	Negative
U11	Yes	No	No	Yes	A few key authors	Negative
U2	Yes	Yes	No	Yes	Key authors and key publications	Neutral
U5	Yes	No	No	No	Very limited a few key authors	Neutral
U7	Yes	No	No	No	Generated a general overview	Neutral
U12	No	No	No	No	A few key authors	Neutral

Table 8.3 Users' overall experience in relation to the generated insight

Looking at the Table (8.3) it can be seen that most users that generated a deep insight were rated as having a positive experience (U1, U8, and U9). This might generate the assumption that positive experience leads to deep insight. However, the table also clearly indicated that these users had

previous knowledge of the concept of DQ which might have contributed to the amount of insight gained. Hence, these assumptions cannot be asserted. In addition, the table also shows the case of U6 who was rated as having a positive experience and yet has merely identified a few key authors. This is due to the fact that she interpreted the task as mainly the need for her to identify authoritative figures in the community when it came to the concept of DQ. This might be due to the fact that identifying key authors is the first step that she would normally engage with when faced with a literature familiarization task.

The table also shows two interesting cases of participants that were rated as having negative and neutral experiences and yet were able to generate deep insight. First, U4 was able to generate deep insight and yet she was rated as having a negative experience. The table shows that this user had previous knowledge of the concept. The negative rating of this users' experience resulted from the way in which she interacted with the tool. From observations of U4's interaction with the tool it was found that the manner with which she interacted with the tool did not take advantage of the visual representation. In fact she relied mainly on the textual data, as seen in Section 8.4.6. She expresses this clearly in the following quotation:

> *"it is just a visual way of following the author tree, um you read the abstract and you try and figure out who is doing what, which is what you do whenever you are researching any topic. If someone gives you a paper you follow the paper trail who cited that person, who that person has cited and look for the same keywords walk down the path* ***I am not sure if the visualization tool actually helped*** *um just because literally you are still looking for a path just because they are in little boxes doesn't necessarily mean its is doing anything different that you would do a list like, so if you go to the ACM you find that paper and you look at who cited it and who it cited."*

From here it can be seen that she used the visual entities such as authors and publications merely as links to navigate the domain as she would have done using a list-based representation (hypertext), such as in digital libraries. Thereafter she would rely on the text based information associated with each of the entities. This resulted in her being able to achieve insight of the concept, and yet not be enthusiastic about the overall experience due to the personal strategy she employed as explained previously.

U7 was able to generate an overview of the key authors and publications in relation to the concept of DQ, yet was rated as having had a neutral experience. The reason can be clearly seen from the comment that he gave when asked to rate his experience, he said:

> *"I would say neutral because ... I think that I found, in theory, what I was looking for, wanting to know who the main authors were in the field and where the main sources of*

literature would be and I found that quite quickly really in that sense it was positive, but the actual use of the tool that looked quite complicated was more on the negative side so I think that overall it would be neutral."

This user has rated the tool's ability in communicating knowledge as the positive part of the experience, but the complexity of the interface as the negative part of the experience as he was *"filled with trepidation"*. As a result, he rated his overall experience as being neutral. As discussed in Section 8.4.7, users who were rated as having neutral experience are users that generally have had positive feelings towards a specific aspect of the experience and negative feelings towards another aspect of the experience.

This discussion demonstrates that insight is very subjective as it depends on users' backgrounds, interests, intentions, or interpretation of the high-level task that were given to them. To conclude this section it is stated that positive experience leads to insight; however insight does not necessarily lead to a positive experience. This can be explained by the fact that users that were rated as having positive experience were enthusiastic and hence their intention to use the tool was higher than, for example, users that were rated as having negative experiences. From here it is argued that, at this stage, it is experience that needs to be the focus of InfoVis design. As a result, insight was excluded from the experience categorization criteria as it is part of the internalization process which is subjective and difficult to capture. To better understand the InfoVis experience it is looked at from the perspective of a theoretical framework known as the instrumental genesis approach.

8.5 The Instrumental Genesis Approach

The GT analysis conducted resulted in the generation of a theory that can be used to describe users' InfoVis experience (Section 8.4.1). In order to reinforce the theory, it was felt necessary to contextualize it in a broader and established area of theoretical thinking which addresses the relationships that users construct with tools. Through extensive reading of Activity Theory (AT) literature, as it reflects a well established theoretical foundation of such concepts, the instrumental genesis approach was identified as its applicability to the findings of the study was striking. The instrumental genesis theoretical framework can be seen as representing the foundation in which the holistic understanding of users' InfoVis experiences can be based. However, before explaining how this is done an overview of the instrumental genesis approach is given.

Instrumentalism or instrumental genesis is a framework that is based on Activity Theory. AT aims at describing the relationship between people and tools (Leont'ev, 1978) whereby tools act as the

mediators between people and the world. Vygotsky (1978) analyzed human activity as having three fundamental characteristics:

- It is directed towards an object
- Mediated by an artefact
- Socially consistent within a culture

Human activity is executed through actions that are administered by the conscious execution of goals resulting in objective outcomes (Bertelsen & Bødker, 2003). These goals are realized through a set of operations performed without conscious thinking on mediators, tools. Activity theory in general argues that the activity cannot be understood without understanding the role of the artefact in everyday life (Nardi, 1996), where artefacts can be reflected as physical tools such as a hammer or a computer, or reflected by sign systems as language. The instrumental genesis framework shares the basic assumptions of AT in addition to being influenced by the French traditions of ergonomic research. This framework adapts the basics of AT whereby people's interaction with the objective world is understood as a socially developing and hierarchically organised activity that is directed towards achieving a specific goal through the mediation of tools. However, the difference can be seen on a more detailed note, where in AT the unit of analysis is the activity, and the tool is seen as the amplifier of thought, whereas from the instrumentalist perspective the focus is on the construction of the instrument which is reflected through the process of creating a mental representation of the tool from the person's perspective. Instrumentalism, as the name implies is a theoretical account that revolves around the instrument.

An instrument is not equivalent to an artefact. In fact, looking at it from a design perspective, the artefact should be designed in order to be efficiently transformed into an instrument by the user (Rabardel & Bourmaud, 2003). An instrument is defined as the psychological construct of the physical object, the artefact. Instrumentalists argue that an artefact does not become an instrument unless the person is able to *appropriate it* as a means to achieving their goals. The process of transforming an artefact into an instrument can be looked at from two different perspectives: a subject perspective and an artefact perspective (Beguin, 2003).

- The subject perspective relies on the ability of the person to develop a *scheme* with which to interact with the artefact; this is referred to as the *instrumentation* process.
- The artefact perspective relies on the ability of the artefact to be *appropriated*, adapted to meet the person's needs, *instrumentalization* process.

Hence, it can be said that an instrument is made up from the artefact and the scheme employed by the user in order to achieve the desired goal. Hence, the artefact becomes an instrumental proposition rather than a finalized design. Instrumentalists argue for the idea of continuous design in usage, this is supported by the fact that the model that they put forward is a generative one. Rabardel and Bourmaud (2003) give a detailed description of this model as seen in the following figure.

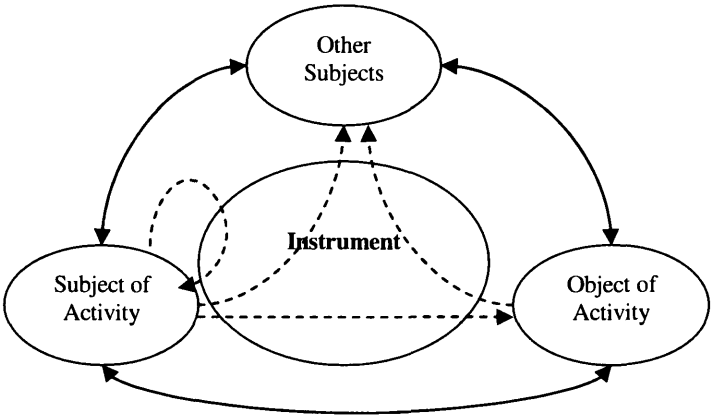


Figure 8.3 Instrument mediated activity (Rabardel and Bourmaud, 2003)

The instrument, the mental representation of the artefact is at the centre of the interaction cycle since it represents the central mediator in the person's activity. The parts of this cycle that are of interest to this research are the ones that intersect with the instrument; in other words, they are the ones that take part in the instrument development process. These are represented by the dotted lines in Figure 8.3. As seen in this figure the mediation in instrument-mediated activities has three main orientations:

- Towards the object, where the subjects' activity is directed towards the object of interest, the artefact. Users' intentions when interacting with the object of interest can either be epistemic or pragmatic (Folcher, 2003):
    - Epistemic mediation: this represents the constructive actions performed by the subject in order to get to know the object
    - Pragmatic mediation: this represents the productive actions performed by the subject on the object such as transformations, etc
- Towards oneself, *reflective mediation,* where the subjects' relation with him/herself is mediated through the instrument. For example, using the instrument to remind oneself of something. Rabardel and Bourmaud (2003) refer to an example given by Vygotsky where

he described such a relation by the example of doing a knot on a handkerchief as a way of reminding oneself of something.

- Towards other subjects, *interpersonal mediation*, this, generally but not necessarily, is seen in collaborations or collective activities.

Each instrument is a mediator of these three relations, where one relation is usually the dominant. In the case of this thesis, the interpersonal mediation is somewhat absent as we did not look at users' collaborative InfoVis experiences. This framework influences design as it clearly states that artefacts are more than merely representational devices, they are part of a mental instrumental construction. Hence, when designing artefacts the following should be taken into account (Kaptelinin, 2003):

- Artefacts should be designed in order for them to be effectively transformed into instruments, in other words allowing for *instrumentation.*
- Users' needs should be taken into account as artefact design is based on them.
- Allow for *instrumentalization* in order for people to be able to modify the design of the tool themselves. This can be seen as designing for appropriation (Dix, 2007).

The concepts and the ideas raised by this discussion relate closely to the findings of the qualitative explained in this chapter.

8.6 InfoVis: From Tool to Instrument

The InfoVis experience is created as a result of users' interaction with the InfoVis tool. This interaction is based on users' past experiences and knowledge and results in the generation of insight. Experience depends on users' harmonious interaction with the InfoVis tool (Figure 8.1). This harmony of interaction is dependent on the relationship between interface related activities, reflected through the visual and physical activities, and the internalization process, depicted by the sensemaking activities. The categories that make up users' InfoVis experience can be logically explained from the instrumental genesis approach. This is done in order to further understand what *harmonious interaction* means from an instrumentalist perspective. This will assist in furthering the understanding of users' InfoVis experiences.

By looking at the users' InfoVis experience from the perspective of the instrumental genesis approach, the model depicted in Figure 8.4 was generated. From an instrumental genesis approach, users' activities when interacting with the InfoVis tools are divided in pragmatic and epistemic

activities. In other words, users' activities are divided into activities that relate to users' actual interaction with the tool and activities that relate to the subject, the user, such as the building of mental models which result from users' sensemaking activities (Chapter 2).

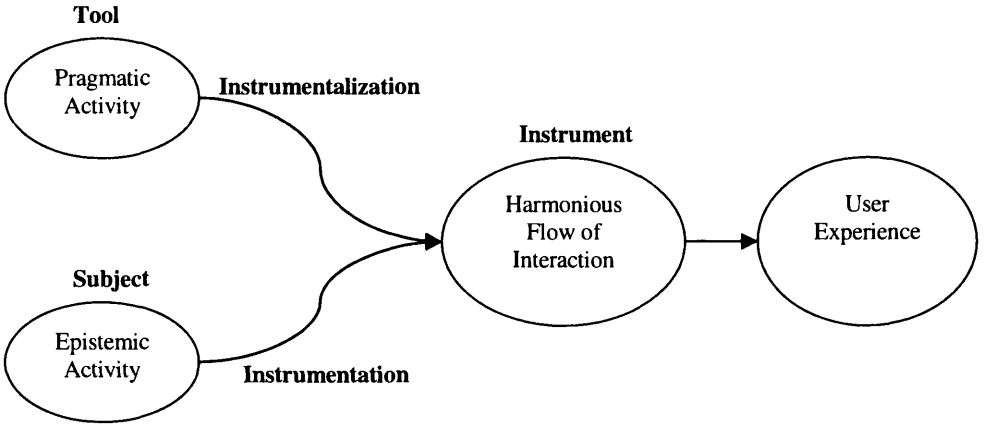


Figure 8.4 Users' InfoVis experience from an instrumentalists' perspective

Pragmatic activities, as described earlier, represent the activities with which the user manipulates the artefact. When it comes to users' InfoVis experience, as describe in Section 8.4.2, these activities reflect the activities that users engage with in order to interact with the interface. To execute these activities within the context of InfoVis the users engage with visual and physical activities. It is these activities that will lead to changes that occur on the visual externalization. From an instrumentalist perspective this is part of the tool's appropriation in order to satisfy the user' needs. This appropriation process is described as the *instrumentalization* process, whereby users appropriate the tool for their own needs. An example of this from the experiential study described earlier is reflected in the change of the visibility of the author nodes through the manipulation of the visibility scrollbar in order for users to focus on the filtered nodes, or zoom in to a particular author in order to reveal the details of the author, etc. *Instrumentalization*, when it comes to users' InfoVis experience, is seen as the process through which changes occur on the externalization.

The other types of activities that take part in users' InfoVis experiences are the epistemic activities. *Epistemic activities* are activities that are constructive, meaning that they do not cause changes in the actual tool but affect the subject, the user, as seen in Figure 8.4. From the context of users' InfoVis experience these activities can be seen as part of the internalization process (Section 8.4.3), which consists of users' sensemaking activities that are executed through the identification of a personal strategy. This complies with the instrumental genesis approach, where epistemic activities are all about users' ability to develop *schemes* with which to interact with the artefact, as discussed

in the previous section. Epistemic activities are part of the *instrumentation* process, as described by the instrumental genesis approach.

The output of both instrumentalization (the pragmatic activities) and instrumentation (epistemic activities) processes leads to the development of the instrument (Section 8.5). From here it can be seen that the instrument sits at the core of users' InfoVis experience (Figure 8.4). Hence it can be said that users' InfoVis experiences will depend on whether the users are able to construct a mental instrument of the InfoVis tool. The instrument construction process is the output of the harmonious flow. As a result, the findings of the study are rephrased by saying that users who are able to create instruments as the result of their interaction with InfoVis tools would have a positive experience, whereas users that are unable to do so will have more of a negative experience. From here it can affirmatively be said that in order for users to have a positive experience the InfoVis tool's design must allow for:

- Instrumentation
- Instrumentalization
- Harmony of flow whereby instrumentalization will support and not interfere with the instrumentation process

The first and second design implications are the main challenges that are being discussed as part of the instrumental genesis literature and are transferable to the context of InfoVis. As for the third implication, this mainly results from the findings of the experiential study. It needs to hold when it comes to the design of InfoVis tools, as users' experiences mainly revolve around the subject related activities, epistemic activities. Instrumentation is a subjective activity that relates to people's background and experiences; as a result, these needs to be taken into account when designing InfoVis tools. These experiences mainly rely on peoples' experiences interacting with the domain of interest. As a result, the following design implications are added:

- Understand the characteristics of the domain
- Understand users' domain related experiences

Details of how this theoretical understanding influences the design of InfoVis tools are not discussed in this chapter as they will be discussed in detail as part of the next chapter, since Chapter 9 focuses on the implications that the theoretical understanding has on the design of InfoVis tools.

8.7 Conclusion

This chapter has presented a detailed qualitative analysis of users' InfoVis experience. This analysis has assisted in generating a testable theory that explicitly lists the components of such an experience. As part of the analysis, users' experiences were categorized into three main categories: positive, negative, and neutral. Interestingly, this categorization demonstrated that the main distinguishing factor between the users in these categories is related to their ability to generate an internalization of the represented domain in a manner that is natural and personal to them. Following the analysis, great resemblance between the findings of the study and the instrumental genesis approach was identified. The study findings reflect a theoretical experiential account of users' interaction with InfoVis tools and the instrumental genesis approach is a theoretical account of people relationship with tools. The instrumental genesis approach takes into account both the pragmatic and epistemic activities which were identified as being an essential part of the InfoVis experience. In order to give strength to the theoretical findings they were represented from an instrumentalist perspective. The generated experiential model is used as part of the discussion presented in the next chapter in which the effects that these findings will have on the design of InfoVis tools.

9. Conceptual and Experiential Design Implications

9.1 Introduction

The aim of this chapter is to discuss the design implications generated from this research. These are divided into two categories: implications generated from users' conceptualizations of the literature domain and implications generated from the theory of harmonious flow. Implications based on users' conceptualizations are domain specific and are based on the results of the studies explained in Chapter 5 and Chapter 8. These will explicitly discuss the design implications of the academic literature domain. On the other hand, the theory based implications are informed by the results of the experiential study discussed in Chapter 8 and explicitly discusses the how a harmonious flow of interaction can be achieved as part of an Information Visualization (InfoVis) design.

Chapter 8 revealed that the domain, as represented via the visualization, is one of the main components which have an effect on users' InfoVis experiences. This is due to the fact that the strategies the users employed in order to guide their interaction with the tool are based on the ability of the tool in meeting and fulfilling their domain related conceptualization needs. As a result, this chapter starts with a discussion of the Academic Literature Domain (ALD) implications. These implications are based on insight gained in relation to the characteristics and the strategies that researchers adopt in order to make sense of its structure and the conceptualizations that they have created of the domain. This knowledge stems from the requirements gathering study (Chapter 5) and the experiential study (Chapter 8). In the requirements gathering study a model of users domain related conceptualizations was generated and, as part of the experiential study, knowledge was gained in relation to the strategies that the users have employed in order to make sense of the externalization. These implications will be discussed independent from possible implications for visualization design demonstrating its generalisability to other sensemaking ALD tools.

In addition to the ALD implications this chapter will also discuss the theoretical based implications as these will have an effect on the design of InfoVis tools. These implications are based on the experiential theory generated in Chapter 8 and will specifically discuss the ways in which a harmonious flow of interaction can be realised between the pragmatic and epistemic activities, where pragmatic activities ought not to interfere with epistemic sensemaking activities. As a result,

these implications are categorized into two categories: design implications that target the interface and design implications that target the externalization. The reason for discussing the theoretical InfoVis design implication from the perspective of the interface and the externalization is based on the fact that the pragmatic activities are the activities that users engage with in order to manipulate the interface, and the epistemic activities are activities that users engage with in order to make sense of the domain as represented through the externalization.

9.2 The Academic Literature Domain Design Implications

The domain is a crucial component when it comes to the design of InfoVis tools. As seen in Chapter 8 users that were rated as having a positive experience were the ones that were able to makes sense of the domain as represented through the externalization. As a result, design requirements shouldn't merely represent domain related entities but should also take into account users' domain related conceptualizations and sensemaking strategies. The ALD InfoVis tool's design was based on researchers' ALD conceptualization which was generated as part of the requirements gathering study (Chapter 5). Such a study gave great insight in relation to the characteristics of the ALD in addition to the strategies that users adopted in order to make sense of such a domain. This knowledge was later reinforced by the knowledge gained in the experiential study conducted in Chapter 8 where users talked about the strategies that they employed in order to make sense of the domain as represented through the externalization.

This section will look at data collected from the study conducted in Chapter 5 and Chapter 8 in relation to the strategies that users adopted in order to make sense of the literature domain. These strategies, in addition the ALD related conceptualizations (Chapter 5) will form the basis of the ALD design implications. However, prior to discussing these implications in detail it is crucial to point to the personal nature of the ALD as it is this quality that forms one of the main challenges in designing tools for the ALD.

9.2.1 The ALD: A personal experience

Researchers, write, publish, and share publications. In so doing they advance knowledge and give themselves a sense of belonging by being part of a community. As a result, they gain knowledge and experience that affects the ways in which they subsequently work with literature, making it a personal experience (Chapter 5). In order to effectively communicate that, examples of personal

differences between the senior and junior researcher will be given from the perspective of the four categories generated in Chapter 5: community, literature, influence, and evolution of a discipline.

Community

Community, as seen in Chapter 5 is what the experience revolves around. It reflects the category from which everything emerges. Junior researches, as opposed to senior researchers, struggle in order to feel part of a community. This can be seen in the comment made by P4, a first year PhD student, indicates:

> *"I don't consider myself to be a very confident ... So I would refrain in saying that I am an expert in a certain area and I contribute to sort of a research community and sort of like in a big way. I consider myself quite junior so I would be very wary about making any claims."*

Comparing this to the comment made by P8, a senior researcher, when asked about her community, she said:

> *"...I see is a kind of research community which will... yeah I'll evaluate their work they'll evaluate mine and we will discuss ideas um related to a particular subject area"*

From here it can be seen that she is more confident in her belonging to a community. This is reflected by the comment she gave regarding her ability in evaluating other members work and her acceptance of other members evaluating hers. It is this level of confidence and knowledge that affects the ways in which researchers work with literature.

Literature

Literature represents the concrete pieces of information from which knowledge is gained. Depending on users' backgrounds and knowledge the ways in which they interact and reason about the literature differs. For example, in addition to looking at the relevant information such as: title, abstract, keywords, etc in order to determine the relevance of a paper, less experienced researchers look at information such as the influence of that particular. For example P2, a 3rd year PhD student, was asked to elaborate on the criteria that he uses in order to determine the relevance of a paper he said:

> *"First of all you look at the title and abstract or you read the whole paper first to determine whether the content is relevant to you but also I guess in terms of the literature, that is why I use web of science to see how many people actually cited this paper, to determine how important it is and you also get the feel of like the players in the field like how important, well not how important, but how big of an impact these people make in contribution"*

From here it can be seen that this is done as a way of giving him confidence in trusting the information that he has found as he does not merely rely on the ideas presented in the paper, he also looks at the number of times that particular paper was cited in order to determine its impact, in other words, its influence on the community. Comparing this to the comment that P3, a senior researcher, gave when asked about the ways in which she looks for general backgrounds of a particular topic she said:

> *"as long as I feel that I have got a representative set of the literature that is what I care about, I am not worried that I have got absolutely every paper about the subject, I'll do one or two keywords in the resources I just mentioned and pick out the references that look most relevant to me, and of course doing it that way you may miss some really key references, but I tend not to worry about that so much if I am doing a kind of general background"*

This maybe due to the fact that as researchers go up the academic scale they become more like leaders of their academic groups, they become more involved in strategic thinking and design rather that involved in working with literature compare to more junior researchers.

Influence

Experience and background does not only affect the ways that researchers work with literature, but affect the ways that they reason about concepts. P3, a senior researcher, gave the flowing comment when asked to talk about what makes an author influential:

> *"There definitely is [an influential author], and one of the frustrations is that I have never managed to put my finger on what makes somebody influential ...I know that such people exist and I think they do have properties like they are naturally more of a self publicist than some of the rest of us um that they are good writers, that they are good communicators ... its not necessarily that they have new ideas but that they can communicate ideas whether they are new or not in a compelling way"*

Interestingly this researcher did not refer to the number of citations as being a factor in determining the influence of an author. This researcher confidently expressed an opinion and was not threatened by the idea of influence or impart as most junior researchers, whereby they mostly characterized influence as equating to the number of citations, as discussed in Chapter 5.

Evolution of a discipline

Generating an understanding of the evolution of a discipline reflects a high-level overview of knowledge that senior more experienced researchers generated as part of their interaction with literature. Junior researchers, on the other hand, are more involved with the details of literature

rather than with such a high-level concept. Following are examples of two first year PhD students when asked whether such a concept was important to them:

P4: "...it is a bit beyond my scope"

P7: "...I suppose it is about what people find interesting and you know decide to invest their time in".

From here, in addition to the data presented in Chapter 5 it can be seen that it is this personal-social aspect of the literature domain that forms one of its main design challenges.

9.2.2 Making sense of literature

Sensemaking is all about the strategies that people adopt, whereby elements need to fit into a structure, a frame as Klein et al (2007) explain which they link to other structures from their past experiences. Making sense of literature is a personal experience that is affected by researchers' backgrounds, knowledge and needs. It is executed through a set of task-based strategies which take part in a complex subjective reasoning process.

Task-specific strategies

Authors produce publications which they co-author with other authors. These publications cite other publications and are in turn cited by other publications. This structure forms the basis of the tasks that researchers engage with in order to make sense of the domain, as revealed by Chapter 5 and Chapter 8. The tasks that researchers engage with are as follows:

- Searching for a particular author if the author is known
- Following citation links (forward and backward chaining)
- Identifying co-authors of a particular publication
- Searching for specific concepts or keywords of publications

These are not listed according to priority, as they are interconnected. It is this interconnection that forms the basis of the employed strategies. For example, P2 was interviewed as part of the study conducted in Chapter 5 and was asked about the strategy that he used in order to work with literature, he said:

> *"I Google first and then I look at who is out there doing that sort of work, I look at those papers and then I sort of accumulate those papers together and then I use web of science... to look for a specific paper and that is a very good tool...you can see who is citing who, cross referencing, and the citation numbers and all of that."*

These strategies are executed as part of a specific path in order to satisfy researchers' needs. This is clearly visible in the following example where U1 is explaining the additional features that he would like to have in the ALD InfoVis tool as part of the experiential study (Chapter 8):

> *"what you want to be able to do is not only identify important papers but identify important authors and identify important conferences and journals as well 'cause that also adds to your knowledge... you have sort of a broader view of the of names of authors and names of conferences and journals".*

The literature sensemaking experience

The strategies discussed earlier are not merely based on factual information, as revealed in Chapter 5 and Chapter 8. There are lots of personal considerations that take part in the execution of these strategies and the construction of related conceptualizations. These are discussed from the perspective of the categories generate in the requirement gathering study (Chapter 5).

Community

The requirements study (Chapter 5) pointed to the fact that users view the community not merely in terms of global communities but also in terms of personal communities. The personal community is a small community that one personally defines. This can reflect a group of people that the researcher is working intimately with, for example:

> *P4: "...the head of this mini research community...will have an impact on where research is going to go"*

Or communities that the researcher sees as being based around a specific conference, for example:

> *P3: "...there is a community that bases itself around a particular conference or a particular set of conferences".*

Literature

Literature, as explained in Chapter 5 is not merely based on concrete information but is based on the ideas, as explained clearly by the following researcher (Chapter 5):

> *P4: "I read a lot about what is going on and try and sort of like make sense of all those ideas"*

Ideas are very subjective and are dependent on the interest and background of the researcher. For example, a user in the experiential study (Chapter 8) said:

> *U9: "it will be nice to add some notes or stuff as you mark it"*

Whereby notes are a medium where the person can express subjective thoughts. Ideas are generated as part of users' interaction with literature, and are not part of the domain's concrete entities. However, they are an essential part of the sensemaking process, as one user in indicated (Chapter 5):

> *P6: "it is not the paper but the ideas".*

Influence

Influence is a major criterion in users' sensemaking strategies, as revealed in Chapter 5. Influence was mainly characterized by the number of citations. However, the number of citations was not the only criterion, researchers talked about particular pieces of work that had a personal influence, for example a researcher who was interviewed in Chapter 5 said

> *P3: "...there have been papers that have been influential ...actually changed the way I have thought of my work".*

Evolution of a discipline

In addition to researchers being interested in the evolutions of disciplines and concepts, Study 1 showed that researchers were also interested in their own evolution. Whereby they did not merely talk about the evolution of a discipline as a whole, but were also interested in the ways in which their research interests have evolved. For example, P3 who was interviewed as part of the requirements gathering study (Chapter 5) said:

> *"It[research focus] changed quite a lot over the years but its kind of emerged in a kind of logical sequence from my PhD work, whereas the [other research interest] was something that we just started because it looked trendy".*

9.2.3 Designing for the ALD

As seen, strategies that researchers employ are quite simple, yet the reasoning and the knowledge that is gained out of it is complex due to its personal experiential nature. In this section we discuss the design implications of the literature domain based on the results of the requirement gathering study (Chapter 5) and the experiential study (Chapter 8).

Entities

The concrete entities are what researchers interact with as part of their literature experience. These can easily be represented as they reflect factual domain information. They are grouped according to the four categories generated in the requirements gathering study (Chapter 5):

- Community
  - authors and their associated research interests
  - collaborations
- Literature
  - Physical link to the actual paper
  - Explicit representation of the source of the publication e.g. whether the publication was presented in a journal or conference and its name
  - Date
  - Citations (forward and backwards)
  - Self-citations
  - Reference of the paper
- Influence
  - Number of times a publication was cited
  - Number of times an author was cited
  - Number of publications of an author
- Evolution of a discipline
  - How concepts have evolved over time

Support sensemaking strategy

A seen in the previous discussion, strategies are based on specifics paths that researchers follow as they are making sense of literature. As a result, keeping track of the information that researchers find interesting throughout the adopted sensemaking paths would assist researchers in extracting and revisiting such information. A preliminary example of this is the marking tool implemented as part of the ALD InfoVis tool, where users were able to freely mark (change the color of) any entities that they found interesting. In addition, an example of this can be seen as part of the CiteSense (Zhang et al, 2008) application where users are allowed to save results of the sensemaking process.

Support the construction of an appropriate understanding

Making sense of literature is a personal experience that results in the construction of an appropriate subjective conceptualization of the domain. To best support that, the literature environment must not merely reflect concrete entities but should assist users in expressing such subjectivity. This is discussed from the perspective of the four categories generated in the requirements study (Chapter 5).

Community

Literature visualization tools exist that presents overviews of communities. For example the hypertext author co-citation map (Chen 1999) (Chapter 1) which presents authors and their associated research interests, and the ALD InfoVis tool which presents an overview of the community clustered according to collaboration. However, as discussed earlier, the community is not merely global. Researchers define communities that are personal to them. As a result, it would be of great value to give the users of literature tools the ability to determine communities of interest, i.e. filter down from global community to a personally defined community. We have no knowledge of existing tools that supports such functionality.

Literature

When it comes to literature, concrete entities can easily be represented either visually as in the ALD InfoVis tool or text-based as in (Zhang et al, 2008). However, the real challenge when representing literature is related to expressing the 'ideas' that are communicated and generated as part of users' sensemaking processes. A few attempts have been made to tackle such a problem, e.g. CiteSense (Zhang et al, 2008) which provides a flexible environment for users to add and structure their thoughts, and ClaiMapper (Uren et al, 2006) which allows users to sketch argument maps of individual papers. Further research is needed to address the presentation of ideas as part of literature sensemaking environments.

Influence

Influence can be represented through the use of concrete entities (number of citations), e.g. as represented in the ALD InfoVis tool. However, the challenge when representing influence is giving the users the ability to express that something is personally influential. We are not aware of any tool that supports this.

Evolution of a discipline

In addition to viewing evolutions of domains for e.g. KDViz (Chapter 4), it would be of great benefit for researchers to be able to determine the concepts and the authors for whom they would like to track their associated evolution trail. We are not aware of any tool that supports that.

Non-linear structure

Last but not least is the debate on whether it would be best to design ALD tools' environments in terms of 2D rather than 1D environment. In terms of this research, having created the ALD tool as 2D visual environment triggered users in the study conducted in Chapter 8 to talk about benefits that such had in assisting them in navigating the environment in a more efficient manner. This is expressed quite clearly by the comment given by U7:

> *"This [the visualization tool] strikes me to be more powerful that than the ACM. ACM it seems a lot more linear you know, A then B then C whereas you are able to do more at the same time"*

In addition to being able to do more, all users in addition to users that are rated as having a negative experience indicated that the 2D visual representation of the community was much better that the traditional list representations in terms of giving overview, this is expressed clearly with what U8 says when asked to compare between his experiences using the InfoVis tool and his experiences using Google, as it was the search engine that he relies on when looking for publications:

> *"Extremely more useful in terms of being able to gather more readily an overview of what is going on, with Google you get no sense of understanding the relationship between people or papers or areas in fact whereas this tool eventually gives you the areas. With Google you would have to spend an awful lot more time going through each and every single thing and also Google has no context in that sense so you got context with this dataset and the visualization really helps"*

From here it can be seen that the 2D environment was beneficial in terms of generating an overview and setting a better context for the sensemaking process. However, further investigation is required in order to confirm such an assertion.

This section has pointed to the design implications of the ALD independent of whether or not it is to be applied to a visualization tool. The literature domain is a structured domain with which researchers follow task-based strategies in order to construct a personal perspective that is affected by the researchers' background, knowledge and experiences. It is this personal stance on literature that gives it its unique qualities. Hence, tools are needed which would allow for users to express and construct subjective understandings over a structured base. These implications will benefit researchers who are interested in developing tools of the ALD. They may take various forms depending on the application at hand. For example, when applying these implications to text-based hypertext tools then publications, for instance, will be presented in terms of hyperlinks instead of having a visual property and citations will be presented in a list rather than a graph. This research is

interested in InfoVis. As a result, the domain's properties will take a visual form and will be represented as part of the externalization as will be discussed in the following section.

9.3 The Theoretical InfoVis Design Implications

The previous chapter concluded that InfoVis needs to be designed as instruments instead of tools. Instruments deliver the subjectivity of the experience as they are cognitive appropriations of the tool. Hence, the question becomes: how to design InfoVis instruments? In order to answer this question the experiential theoretical model generated in the previous chapter is re-examined. This model argues for a harmonious flow of interaction between the pragmatic and epistemic activities. In this model, users engage in two sets of activities: tool related activities with which they manipulate the interface; and domain related sensemaking strategies with which they make sense of the represented externalization.

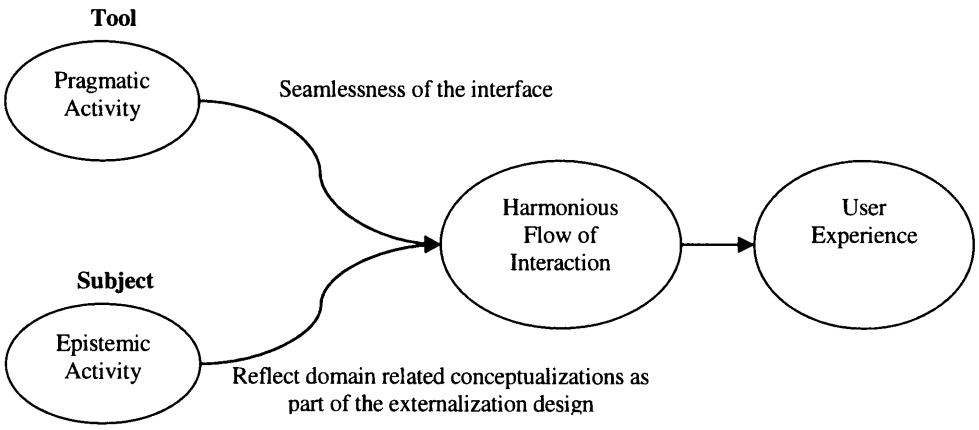


Figure 9.1 The InfoVis experiential design model

In order to describe the design implications of this model, it is looked at from the perspective of users' activities (Figure 9.1): designing for the pragmatic activities and designing for the epistemic activities. Designing for the pragmatic activities needs to take into account both the physical activities and the visual activities. In order to do so, it is suggested that one should design for seamlessness of the interaction which can be realised through the implementation of the instrumental interaction model, as this model takes into account the association between the physical manipulative activities and the interface.

Designing for the epistemic activities takes into account the design of the visual externalization in a manner that would allow for users to make sense of the domain naturally. As a result, should take

into account the conceptual characteristics of the domain in addition to domain related sensemaking strategies (Section 9.2). Throughout this discussion some quotations will be used from the study conducted in Chapter 8 and others will be used from the study conducted in Chapter 5 specifically when it comes to discussing the design implications of the externalization. In order to contextualize the argument there will be constant reflections on the design of the ALD InfoVis tool by presenting redesign ideas.

9.3.1 Designing the Tool: Pragmatic Activities

As discussed in the previous chapter, the pragmatic activities are the activities that users engage with in order to manipulate the interface. They are divided into physical and visual activities. These activities need to be designed in a way that will allow users to interact with the visual activities without interference of the physical activities, since this interference affects users' experiences. Hence, seamlessness of the interaction is argued for, which can be realized using the instrumental interaction model (Beaudouin-Lafon, 2000) which was discussed in detail in Chapter 3. This discussion starts by discussion the concept of seamless interaction which takes into account the harmony of interaction between the visual and the physical activities. Following the discussion of the concept, a discussion of how the concept maybe applied through the use of the instrumental interaction model to the design of InfoVis is discussed. This is done by reflecting on the design of the ALD InfoVis design and consequently generating redesign ideas.

Seamless interaction

When talking about the interaction flow U8 commented:

> *"I [like] to make more of a direct link between button and information rather than a dynamic...Actually cause its [publication view] got a simple 1 to 1 relation between what you click and what you see rather than here [author collaboration/author citation] you know that there are rather several things going on in the background therefore it is a more complex scheme to actually understand what is going on. But that is an overview and that is details".*

In this example the user is referring to the relationship between the design of the physical and the visual activities. He is indicating that he prefers a 1 to 1 relation between the physical and the visual representation. When clicking on an author he immediately got all the publications of that author, which were also represented visually through the size of the box. On the other hand, if he wanted to see the citation information of that author then he would have to drag the authors into the citation view to see the citation information. However, the citation information is not depicted visually as

part of authors' visual representation. Hence, the association between the physical and the visual activities needs to be more carefully considered as part of the design.

Both the visual and the physical activities rely on cognitive processing. The qualitative analysis (Chapter 8) has shown that there is a need to reduce the cognitive processing associated with the physical activities in order to allow for uninterrupted domain related sensemaking activities which relies mainly on the perceptual visual activities. This is what is meant by the seamlessness of the interaction within the context of this research. The experiential study (Chapter 8) has shown that users that were having a positive experience did not seem to pay much attention to the physical activities. This complies with Heidigger's notion of readiness-at-hand (Heidegger, 1962) where everyday objects are being used without theorizing, e.g. using a hammer. The design of InfoVis interfaces should provide such a usage when it comes to the manipulative physical activities. Users need to be able to use the physical activities without theorizing. This can be done by relying on users' interface related internal models. For instance U6 commented:

> *"most of the actions like clicking are similar to most of the other applications I think that one is good because even though there are lots of information given to me during the training I can just guess, like maybe by right clicking or panning, because they are consistent with other applications".*

Having a design that complies with these models assists the user when it comes to interacting with the tool. However, in certain cases these models differ from one user to the other. For example, two users gave conflicting comments when talking about the same physical activity, zooming:

> *U4: "I noted that the zooming was working in the opposite direction from what I was used to. It frustrated me.... Um plus that is* ***my expectation*** *because I work with graphic tools...and they work slightly differently and that is the only reason.".*

Whereas U1 commented:

> *"I found that easier than I expected um I think what happened is a lot of my intuitions were satisfied and you know the* ***zoom is really nice*** *and the drag, dragging in the space is really nice".*

Satisfying all users' experiences is an impossible task. However, HCI research has done a lot in delivering a natural and intuitive interface related experience by introducing models that are based on users' natural abilities; for example, Direct Manipulation (DM) interaction model which was discussed thoroughly as part of Chapter 3. However, the DM interaction model as explained by Shneiderman (1983) does not explicitly take into account the relationship between the physical and the visual activities. Yet this has proven to be essential for users' InfoVis experience. As a result,

relying on the instrumental interaction model, introduced by Beaudouin-Lafon (2000), and discussed in Chapter 3, is recommended.

Instrumental interaction

Instrumental interaction was thoroughly discussed in Chapter 3. Instrumental interaction was applied as the main model behind the design of users' interaction with the tool. The details of this can be found in Chapter 6. When designing the manipulative activities they were looked at in terms of primary and secondary activities. The primary activities are the activities that are executed by the user whilst the users are in the process of making sense of the domain. Whereas, the secondary or transitory activities are the activities that are performed by the users as they transition from one task to the other such as: searching, filtering, etc. As part of the experiential qualitative analysis done in Chapter 8, this distinction was reemphasized as it was apparent that users can deal with spatial distances, and time delays between the instrument and the object of interest when it comes to transitional, secondary, actions. However, they are less tolerant when it comes to primary actions. Looking at these manipulative activities from the perspective of the instrumental interaction the following is recommended.

Degree of indirection

The design of the primary activities should reflect a low spatial and temporal offset, where spatial offset is defined as the distance between the logical part of the instrument (e.g. widget) and the object it appears on, the object of interest. Temporal offset is defined as the difference in time between the physical action on the instrument and response on the object of interest. This scheme was applied for the design of the ALD InfoVis tool (Chapter 6) except when it came to the functionality of displaying the details of the publication. As a result, this affected the experiences of some of the users as some of them expressed frustration as they did not want to have to perform several physical activities, right-click to view the pop-up menu then click on the details option, in order to view the details of the publication.

This can be explained by the fact that viewing the details of a publication is a primary action. The way in which it is executed at the moment has a high temporal offset, where the user activates the instrument by right clicking on the publication icon, and then needs to scroll down and click on the show details option.

Ideas for Redesign

- As the user double-clicks on a publication then the details of the publication should be shown immediately.
- Expanding and collapsing the citation graph should be done using the pop-up menu option and not by double-clicking as the priority of viewing the details of the publication is higher than expanding or collapsing the citation tree

Degree of integration

Degree of integration measures the ratio between the number of degrees of freedom (DOF) provided by the logical part of the instrument to the number of DOF demonstrated by the physical part of the instrument. This should be taken into account when designing the manipulative activities; if it is not then it might affect users' experiences. However, this cannot be claimed with confidence as all manipulative activities of the ALD InfoVis had a degree of integration of 1 (Chapter 6).

Degree of compatibility

Degree of compatibility measures the similarity between the physical actions of the users on the instrument and the response of the object. This is applicable for the dragging and the zooming actions. When it comes to the dragging action, there is great compatibility between the users' physical action on the mouse and the response on the object, as the object follows the movement of the mouse. The problem however arises with the zooming action, where it is executed using the mouse wheel. There is an incompatibility between these two actions as when the user scrolls in (up) the display zooms out, and when the user scrolls out (down) the display zooms in. Users that had a negative experience picked up on this incompatibility.

Ideas for Redesign

- Reverse the zooming action in accordance with the mouse wheel's actions.

It can be seen that applying the instrumental interaction model assisted in identifying and understanding the problems that arose with users' interaction with the tool's interface, especially when it came to the actions that were related to the main sensemaking activities that users engaged with.

9.3.2 Designing the Externaiization: Epistemic Activities

Users interact with the externalizations through their engagement in epistemic activities with which they make sense of the domain through the execution of personal strategies and schemes. Epistemic activities are subjective as discussed in Chapter 2. The question that needs to be targeted is: how does users' domain related conceptualizations and sensemaking strategies become incorporated as part of the externalization design? This section looks at the design implications of the ALD (Section 9.2) from the perspective of InfoVis design, more specifically the externalization design. The experiential theory generated in Chapter 8 pointed to the fact that the more the externalization is related to users' internalized conceptualization of the domain the better the experience, as it would allow users to employ these internal models to make sense of the domain in a natural manner. As a result, the design of the externalizations needs to take into account the characteristics of the domain that is being represented from the perspective of users' conceptualizations of the domain.

Externalizations and the subjectivity of the experience

Externalizations are the essence of InfoVis tools. Tweedie (1997) describes InfoVis tools as interactive externalizations. External representations are all around us, e.g. written text, signs, graphs, symbols, etc. Zhang (2001) defines them as physical symbols, objects, or dimensions, which are governed by rules, constraints or relations. They form the basis of knowledge and structure in the surrounding environment. Within the context of InfoVis, externalizations are the means with which data is visually presented. Users perceive this representation in order to gain insight and knowledge of the represented domain through their engagement with natural perceptual abilities. In most common cases, this is based on visual perception, whereas in others this might be based on auditory perception (Spence 2007). Zhang (2001) argues that externalizations are not merely inputs or memory aids. They are the drivers of users' interaction, whereby they determine the information that can be perceived and the process with which users' intentions can be executed. He shows that much can be learned about the internal mind through the study of external representations and that they should be studied on their own, not as peripherals of internal representations. On the basis of this, he proposed a theoretical framework for external representation problem solving and used this framework as a methodology to analyse the structure of Tic-Tac-Toe and make behavioural predictions. These predictions were later tested through a series of studies. These studies have revealed the importance of external representations when it comes to cognitive tasks.

Anderson (1993) and others have indicated that internal representations are reflections of external representations. This precisely relates to the finding of the experiential study (Chapter 8) whereby it was identified that the experiential component that negatively affects users' overall experience is based on the miscommunication between the design rationale of the tool and users' internalizations of the world, which, within the context of this thesis, is specifically related to the academic literature domain. For example, if the user is used to making sense of the domain in a certain manner and the externalization does not comply with that then this affects the experience negatively. This is due to the fact that the user is unable to accomplish the desired goals in a natural manner. Spence (2001) refers to this as 'resistance to change'. He gives the following example (pp. 96): "In the event that I have to consult the London underground map to enhance my mental model of the part I plan to traverse I would expect to see, pasted to the wall of the station, the familiar map. However, if overnight, someone had removed all the Underground maps and replaced them with new maps printed upside-down, but with the lettering upside-up, then my browsing and interpretation of the (perfectly valid) map would be far more difficult, simply because of the challenge of simultaneously understanding two maps, one internal and one external". This is what mainly happened with the users that we rated as having had a negative experience, whereby their mental images of the domain did not correspond with the models presented by the tool. For example, one of these users clearly indicated that he was used to *seeing* the literature domain in term of publications and not authors. However, the design rationale adopted by the tool presents the information mainly based on the authors. Hence, the user found it difficult as he was struggling with a mental *resistance to change*.

Externalization, when it comes to InfoVis, guides the personal strategies that the users employ to execute their goals. These strategies are based on the means with which the users make sense of the represented domain, which in turn is affected by the internal models that the users have built as part of their past experiences. The internal models that the users possess affect the weight that users give to the entities that they examine as part of the browsing activity (Chapter 2). For example, some people when interacting with the ALD visualization tool (Chapter 8) mainly explore the authors that had a higher number of publications whereas other users explored the authors that have published highly cited papers. The weight that users were giving to such entities affected the general strategy that they employed. It is important to note that this weight is subjective and hence differs from one user to the other depending on their experiences and backgrounds.

From here it can be seen that even though the externalization, as an entity, is in itself static, yet users' experiences are quite subjective. Hence the goal is to take this subjectivity into account when

designing the externalization, whereby the externalization design must reflect users' conceptualizations of the domain.

Reflecting the domain related conceptualization

The represented domain is a major component that has a direct effect on users' experience (Chapter 8). Each domain is different with it having its own identity and characteristics, which would consequently have an effect on users' needs, in addition to the way in which they interact and make sense of the domain. These experiences need to be expressed as part of the design of the externalization. Capturing these experiences is part of the requirements gathering. Requirement gathering has been considered a necessary step in the development cycles of software tools for years. However, the experiential study (Chapter 8) has shown that the act of requirement gathering for InfoVis tools need not merely rely on generating the data entities and their associated relationships, but also needs to capture users' conceptualizations of the domain. The design implications of the ALD based on users' domain related conceptualizations was discussed in Section 9.2. These implications when applied to InfoVis design assists in determining the layout and the overall design rationale, for example:

- Determining what constitutes the overview and what constitutes the details
- Determining the sequence of actions that the user will need to go through to reveal an externalization of a specific aspect of the domain
- Determining the layout of the externalization and the techniques associated with the presentation e.g. fisheye representation (Furnas, 1986), bifocal display (Apperley, Tzavaras, & Spence, 1982), magic lens (Stone, Fishkin, & Bier, 1994), etc.

This was done as part of the design rationale of the ALD InfoVis and discussed in Chapter 6. This rationale was based on the model generated in Chapter 5 of users' conceptualization of the ALD where the overview reflected the authors, the details reflected the publications, and ideas were looked at as part of the interaction. The experiential study has shown that the prototype missed two essential characteristics, as reflected by the comments given by the users: these were the tangibility of the domain and the integration of the tool with other literature tools which had a negative effect on some users' experiences.

Tangibility of the domain

When it comes to the tangibility of the domain, the requirements study (Chapter 5) indicated the fact that the publication itself is an essential part of the domain related sensemaking activity. Even

though it was at the lowest level (Figure 8.2), it is an essential component that the tool did not deliver. The reason was that the papers, or links to the papers, were not part of our dataset, and since this is a prototype, at that time it was felt that it was not crucial as it was not part of the dataset. After performing the experiential analysis it was realized that this was essential as the task given to the users required them to interact with textual content. Abstracts, which were provided by the tool, were not enough. The availability of the actual papers would have radically changed the experience of some of the users. Researchers when interacting with their literature put a lot of effort and time into the process, which varies depending on the task they are trying to accomplish. Regardless of these efforts, researchers always tend to keep a tangible version of their findings, either stored in an electronic format or printed on paper and filed. During the design of the tool we have not given this part of the sense making process much consideration. In other words, we overlooked the ending stage. This however, was commented upon by some of the users, e.g.

*U9: "I would like to have more ...marking to kind of give you **some report** or **some list**".*

Researchers store the results of their literature related sensemaking efforts for various reasons:

Keep track of the results: U1 commented: *"What I would've really liked to have had is to have **a running list of what a marked list was** I mean screen space is restrictive but as well as being able to see them visually to have a list somehow it would have felt satisfying that was my thing that I was going to walk away with, that that was my package kind of thing, that is my solution"*. It can clearly be seen from this example that this has an effect on the feelings that the user generates of his interaction with the tool. This can be explained by the fact that the user did not want his efforts to go in vain; in fact he needed a tangible manner in which to keep track of his efforts.

Social factors, whereby researchers tend to share their findings with other researchers. U6 explicitly asked if there was a way to store the marked list; when the researcher asked for the reason she said: *"If I wanted to show anyone it will be easier for me to directly go back to"*.

From here it is evident that the experiences provided by the tool needs to be more than transitory; it should be able to take the user from beginning to end, i.e. permanent.

Integration with other tools

Another feature that was also overlooked is the integration of this tool with other literature tools. Even though this can be seen as a future functionality, yet it will have a great effect on users' experiences, as researchers when working with literature tend to use various tools, which they

integrate as part of their activity. Tools such as word processors, reference managers, databases etc are all part of the process. Our tool at the moment is a stand-alone tool. Some users commented on the fact that they would like to integrate this with other tools, for example U12 said:

"I like to be able to export a list of publications with the abstract or something like that".

As a result, it is strongly believed that when evaluating InfoVis tools that the prototype should, as much as possible, be able to deliver a complete package with which users are able to realize more realistic experiences. However, this will always be a challenge due to the time constraints and manpower involved in creating research related prototypes. Based on the previous discussion, the following are redesign ideas.

Ideas for Redesign

- Incorporate links to the actual publications.
- Generate lists of anything that has been marked by the users, and allow the users to export such links, which will include the references of the publications.
- Allow the users to store the interactive session, whereby they are able to return to the visualization and view the previous lists that they have marked.

The ALD InfoVis tool and the design implications

Looking at the ALD design implications discussed in Section 9.2 from the perspective of the ALD InfoVis design it can be seen that the tool was designed in a manner that provides support for most of the researchers' sensemaking needs where users are able to execute all the necessary sensemaking tasks listed in Section 9.2. This is indicated from the fact that researchers who were rated as having a positive experience were able to make sense of the tool in a natural manner.

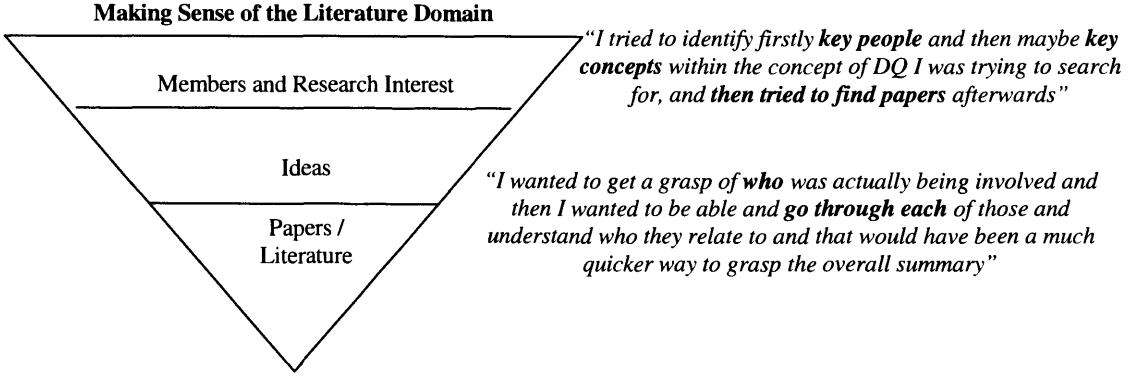


Figure 9.2 Users domain related conceptualization in relation to the design rationale

Figure 9.2 demonstrates the design rationale (the inverted triangle) extracted from the qualitative study conducted in Chapter 5 and some quotations extracted from users that participated in the experiential study (Chapter 8) that were categorized as part of the positive experiences category. The aim of this figure is to demonstrate the way in which people talked about their sensemaking strategies and how this fits with the design rationale of the ALD InfoVis tool.

Section 9.2 discusses in detail the design implications of the ALD. Looking at these implications from the perspective of the design of ALD tool it can be seen that the tool satisfies the base structure of the domain where most concrete entities are represent visually. In addition, it supports researchers' sensemaking needs, as discussed earlier. However, the ALD InfoVis tool lacks in providing an environment that would support users in creating and expressing their own personal conceptualization of the domain. In order to address that personalization is suggested.

9.4 A View into Personalization

Personalization came up as a design implication of the requirements study conducted in Chapter 5. However, at that stage of the research it was not clear how to personalize InfoVis tools, whereby users would be allowed to add their thoughts and views over the externalization generated by the tool. In Chapter 6, as a result of the requirements gathering study a manipulation feature, which was referred to as the 'marking tool' was added. The aim of this tool was to allow users to highlight entities of interest, whether authors or publications.

9.4.1 Examples of personalization

The success that the marking feature had with the users was truly unexpected as users seemed to use this tool differently depending on their goals, i.e. they appropriated it to meet their own needs. Following are a few examples:

Subjectively filter the data - U1 said: *"having a sort of representation of what responded to a query term and then being able to go through them and* ***put my own****, so its like a two step filter so the system filters and then I filter that was really useful."* The user used the word "my own" to refer to his experience in using the marking tool. He indicated that he was able to further filter the data by overlaying his filtering scheme over the system's filtering by marking some of the results of the system's filtered outputs.

Set landmarks - U6 said in relation to the marking tool's benefits: *"I won't feel lost I can go back"*, similarly U11 said: *"I started marking because I looked at stuff and then I moved on and then I came back to it and I realized I actually read that but because I hadn't marked it I did not realize I had read it"*.

Keep track of the amount of work – U10 said: *"I have a sufficient amount of papers actually from it being highlighted so I know that I possibly have a sufficient background for this particular reason"*.

Generate personal overviews – U8 expresses: *"I remember um searching names, marking the authors and then towards the end I remembered that you could mark all the associated authors which is a really handy little thing if you want to get a grips with much of the overview much more quickly"*.

From these examples it can be seen that the users were able to associate different meanings that were personal to them to the marking color (green). Hence, it is argued that such a feature was successful in allowing users to express the subjectivity of their experiences. The marking tool was not the only functionality from which a sense of personalization was generated. Surprisingly, one user used the visibility scrollbar, and added his interpretation over its functionality. The visibility scrollbar, as explained in Chapter 6, is a tool that affects the visibility of the nodes in the main collaboration window. By physically dragging the scroll button the user is able to gradually change the visibility of the non-highlighted nodes. U3 gave the following comment:

> *"I had the filter kind of the slider bar all the way down so I was **just looking at Dynamic Query stuff**"*

From here it can be seen that the user was using the scrollbar to further filter that data, and by filtering he meant, the ability of merely seeing the highlighted nodes, which result from the searching feature. In other words, he was able to personalize the visual externalization by hiding the irrelevant entities.

9.4.2 Incorporating personalization into design

Personalization of InfoVis is a subject that has not been fully researched. There have been a few attempts such as the idea of adaptive-annotations where users' annotations are added to cells (Brusilovsky, Ahn, & Farzan, 2007). Personalization functionalities, especially like the marking feature, have proven to be an effective way to allow users to express their own personal views. The

availability of this tool not only allowed users to express this subjectivity as part of the interactive experience, but also pointed to the need for additional personalization features.

Personalization features, as suggested by this research, are interface related functionalities that affects the visual externalization of the data. Chi (2002) categorizes manipulative operations into two categories, operational and functional. Operationally similar operators are operators whose implementation is the same across the different applications, such as: zoom, rotate, translate, etc. Functional operators are operators whose implementation differs from one tool to the other but have the same meaning across applications, such as filtering. In order to cater for personalization, this research argues that this categorization needs to be taken a step higher by looking at them from the perspective of users' interpretation of the semantics that the user associates with the visual feedback and whether or not this interpretation is subjective to the user or predetermined by the designer. As a result, manipulative operations can be looked at as being either *formal* or *informal,* based on the cognitive dimension of "secondary notation" (Blackwell et al, 2001).

Formal operators are operators that have a specific purpose when it comes to their communicated semantics, as they are predefined by the designer e.g. zoom, filter, rotate etc. Formal operators can be either operational or functional as their intentions are predetermined by the designer. An example of an operational operator is the zooming operator since all the users who used the zooming feature of the ALD InfoVis tool used it for the same purpose: they zoomed into the authors' view in order to be able to see additional details and zoomed out of that view in order to view the overview of that representation. Looking at the zooming action from a wider context, it is clear that the semantics of this operator is the same across the different applications, where users zoom in to see the details and zoom out to view overviews. The same applies to the functional operators, e.g. filtering operator, where all users use such an operator to filter out undesired information. This indicates that the semantics of such a feature from the users' perspective is consistent with the designers' intentions. Most of the operators that are taking part of the design of InfoVis tools are objective ones. Taking for example, the operators defined by Shneiderman's (1996) information seeking mantra, which are: overview first, zoom and filter, details on demand, relate, extract and history. All of these operators are objective as their design intentions and use interpretation are the same.

Informal operators are operators whose semantics can be freely appropriated by users depending on their own needs. An example of this is the marking tool discussed earlier. Other examples of such functionality can be to give the users the freedom to categorize or group visual entities, add objects to a list, delete or hide specific entities as U1 expressed:

> *"I think if it had been possible to **delete items** like a **mind map** then I think that I probably would have continued and made it more expansive, I even would have wanted to walk away with a printout, that sort of thing."*

The difference between formal and informal operators lies on the fact that informal operators are operators that do not rely on computational algorithms. Rather, they are imposed by individual users to assist them in their sensemaking efforts. Following are a few suggestions given by users who participated in the experiential study (Chapter 8). Experiencing the personalization tool motivated the users to talk about their need for more of such tools, whereby they were referring to the concept of 'mind maps'. In addition to the example given in the previous paragraph U3 said:

> *"it [the literature InfoVis] is one of the things that I always wanted to do with my reference manager ... some kind of **mind mapping** thing, so it is almost that I can take notes and be like I think that these two can go together and almost like create **my own information visualization**".*

In this example it can be seen that the user compared the experience of using the tool to something that is similar to a mind mapping experience whereby he wanted to create his own InfoVis. Mind maps are diagrams that people create in order to represent ideas, words, and concepts (T. Buzan & B. Buzan, 2000) for the purpose of furthering their understanding. They are created by the user and are rather personal. When users interacted with InfoVis tools, and more specifically academic literature visualization tools, they expressed the need for a personalized experience, as U3 explicitly stated: *"my own information visualization"*. Users need additional functionalities that would allow for such personalization, as one user indicated:

> *U9: "it will be nice to **add some notes** or stuff as you mark it... not who cited who but also **for what purpose**... I would **put more weight** to papers".*

In this example the user explicitly gives suggestions for some of the features that he felt necessary to enhance such an experience. Personalizing InfoVis tools is an interesting question that needs further investigation. However, for the time being it suggests designing for appropriation as introduced by Dix (2007). Dix discussed the fact that design features should be flexible and not rigid in a way that allows users to employ them for various unanticipated purposes. As users interact with these features further personalization ideas will be generated and further needs will be expressed. This is exactly what happened when users were interacting with the marking tool, as expressed earlier, which led to the generation of the following ideas for redesign.

Ideas for Redesign

- Adding features that comply with the design for appropriation concept; the following are a few examples:
    - Give the users the option to mark entities in various colours and associate a meaning to each. For example, users can mark relevant entities in one color, and irrelevant entities in another.
    - Give the users the option to add weights to the links between entities; this will assist users in adding their own personal interpretation to the citation links. As a result, the users will be able to identify whether or not the citation is crucial to them.
- Allow the users to add to the dataset in order to be able to see whether their literature fits within the context of the domain
- Give the users the freedom to hide entities.

9.5 Discussion

This chapter has discussed the design implications that this research has generated. These were categorized into implications which are based on users' conceptualizations of the ALD and implications that are based on the theory of harmonious flow. The domain specific implications discussed the design implications of the ALD based on the knowledge gained of the conceptualization and strategies that users generated of the ALD (Chapter 5) and applied in order to make sense of such a domain (Chapter 8). These, as discussed in Section 9.2, are independent of any particular tool, whether it being visualization or not. The theoretical implications (Section 9.3), on the other hand, discussed the design implications of InfoVis tools based on the results of the experiential theory (Chapter 8). These were related to achieving a harmonious flow of interaction between the interface and its associated externalization. Looking at it from this perspective, it may seem that the domain and theoretical implications are separate. However, based on the results of this research they are very much interrelated, as shown in the following figure below.

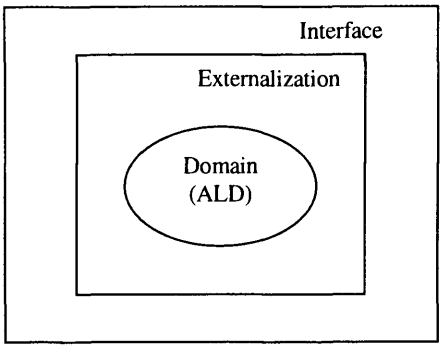


Figure 9.3 The domain is the soul of InfoVis design

The domain and its associated design implications form the centre around which the InfoVis tool is designed. It is reflected as part of the externalization which in turn is represented as part of the interface. It is via this interface that the users are able to interact with and communicate their desires to the tool. Users when interacting with the interface, do so through a set of direct manipulation activities (Chapter 3) whereby widgets are mediated through input devices. This interaction is done via a set of goal-directed actions (Norman, 2002), for example, the user clicks on an author in the interface and all publications of that author are displayed. However, looking at the nature of the domain that is being represented in this research, which is the ALD, in addition to the strategies that users employ in order to make sense of it (Section 9.2) goal-based planning models are not representative of users' overall actions in interacting with InfoVis. A goal-based planning model merely represents the low-level interface related activities, as indicated. It is important to note that goal-based planning models have been subject to critique in HCI e.g. (Suchman, 1987).

The experiential theory generated in Chapter 8 argues for the importance of taking both interface related activities in addition to domain related sensemaking activities into account when designing InfoVis tools. In order to do so there should be a deep understanding of the nature of users' interaction with the interface and its associated externalization (Section 9.3) in addition to a deep understanding of the domain (Section 9.2). The social and conceptual nature of researchers' interaction with the ALD has resulted in a complex set of design implications some of which have been addressed in the design of the ALD InfoVis tool (Chapter 6). As for the rest, specifically the ones that are related to the construction of an appropriate understanding, personalization was suggested. Due to the time constraints associated with this research, in addition to complexity of the some of these implications will be considered as part of the future work.

9.6 Conclusion

The experiential study conducted in the previous chapter was based on an exploratory analysis approach, GT, which is uncommon especially when it comes to InfoVis research. The use of GT has allowed for the theoretical grounding of users' experiences interacting with InfoVis tools. This theoretical base has allowed for the reflection on design in a manner that could not have been done otherwise. As a result of this, redesign ideas for the ALD InfoVis tool were generated. These design initiatives are based on delivering a harmonious flow of interaction between the pragmatic and epistemic activities. Where the pragmatic activities address the interface design and the epistemic activities address the externalization design. The externalization design is specific to the represented domain and hence must effectively represent domain related conceptualizations and support the associated sensemaking strategies. As a result, domain related implications were generated and later discussed from the perspective of the externalization design. To support these implications personalization was suggested as a means for providing an environment where users can effectively construct an appropriate understanding of the domain. Further work needs to be done in order to investigate these findings further. These will be discussed as part of the next chapter, the conclusion.

10. Conclusion

How can we design good InfoVis tools? This is the overall aim of this thesis. Coming to the end, has this research been able to accomplish it? The answer is both yes and no. Yes, due to the fact this research has started to unpack what constitutes a "good" InfoVis tool by generating a grounded theoretical understanding of users' interaction with InfoVis tools. This was done by looking at interaction as an experience and by exploring the relationship between the user and the tool. No, due to the fact that there is still more work that needs to be done in order to come up with a fully operational theory. This research has taken a first step in developing a theory of users' interaction with InfoVis tools, and calls for researchers in the field to contribute to it, as it is my strong belief that designing InfoVis tools that rely on an InfoVis theory of interaction and not a generalized HCI model will enable the InfoVis community to start to develop good InfoVis tools.

10.1 The Motivation and the Overail Contribution

The nature of users' interaction with InfoVis tools is highly cognitive due to the fact that users need to make sense of the externalization in order to generate an internalization of the represented domain. However, this cannot be done without users' engagement with interface related manipulative activities. This research has shown that in order for a positive experience to arise, there needs to be a harmonious flow of interaction between the internalized sensemaking activities and interface related manipulative activities.

By relating these findings to the motivation of this research (Chapter 1), which was based on the relationship between the externalization and the interface, it can be said that user experience within the context of InfoVis is equivalent to the *harmony of interaction* between the interface related activities and externalization related activities. Usability is not sufficient for evaluating InfoVis tools due to the nature of the activities, as usability concentrates mainly on the interface and its associated manipulative activities. This research has shown that both externalization related sensemaking activities and interface related manipulative activities are crucial for the delivery of a positive interactive experience.

In order to reinforce the theory, it was felt necessary to contextualize it within an established theoretical framework. The instrumental genesis framework (Rabardel & Bourmaud, 2003) was determined as being the most suitable as it reflected the umbrella under which users' InfoVis experiential model fitted soundly. Through the use of this framework, users' interaction with the InfoVis tool is seen as being reflected by a continuous process of instrumentation and instrumentalization activities. As described in Chapter 8, instrumentation reflects the activities that users engage with in order to make sense of the domain as represented through the visual externalization. These are the epistemic activities. The instrumentalization reflects the activities that users engage with in order to manipulate the interface, the pragmatic activities. As a result of this continuous harmony of interaction, a positive experience arises. This conclusion complements the call that Beaudouin-Lafon (2004) makes for the design of interaction and not interfaces. Users' interaction with InfoVis tools is the essence of the experience, whereby it is characterized by the ability of the user to fully transform the tool into an instrument, where an instrument is a mental appropriation of the tool.

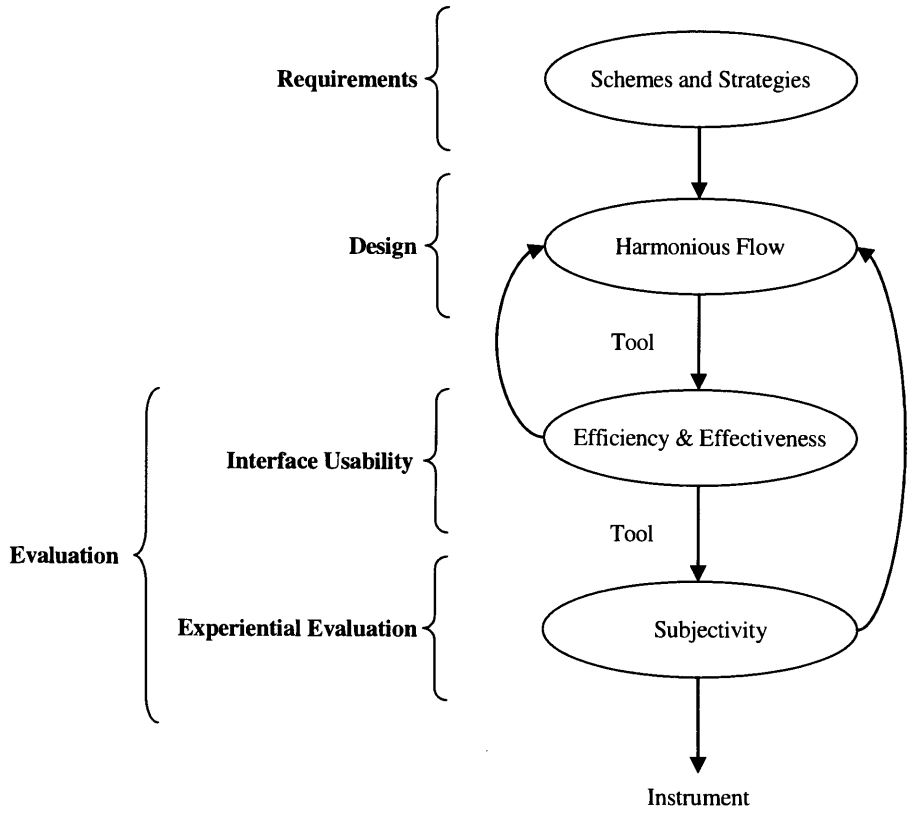


Figure 10.1 Design and evaluation of an InfoVis instrument

In order to conclude this thesis, the contributions that this research makes will be looked at as part of an overview of the design and evaluation process taken by this research in order to design and evaluate the ALD InfoVis tool. This process is presented in Figure 10.1 and starts with the requirements gathering and ends with the evaluation of the tool. Each step of this process will be discussed in terms of the contribution that it offers. Contributions of this researcher were briefly listed in Chapter 1 however in this chapter they are contextualized within an instrumental InfoVis design and evaluation process. This process, as seen in Figure 10.1, is an iterative one that goes back to design after the completion of each step. In addition, it addresses one of the contributions of this research as it reflects a User Centred Design (UCD) process for the design of InfoVis tools.

10.2 Requirements: Capturing the Schemes and Strategies

The requirement gathering step addresses two of the contributions of this research which are targeted towards the application domain, the academic literature InfoVis domain. These contributions are:

- Identifying a descriptive theory of how researchers make sense of their academic literature domain
- Generate the design requirements of the academic literature domain

This research has identified that in order for InfoVis tools to reach the user, they need to be designed in a way that will allow for a natural instrumentation process. One of the criteria of this is the ability of the users to make sense of the domain are represented by the externalization in a natural manner. Hence, the design of the externalization and its associated interface related interaction scenarios needs to reflect users' experiences with the application domain, making requirements gathering an essential step.

The requirement generation process should not merely involve going out and asking users what their requirements would be. In fact, as explained in detail in Chapter 5, this process involves generating a deep understanding of the processes with which users make sense of and reason about the application domain, i.e. domain related conceptualizations, which in this case are researchers' conceptualizations of the academic literature domain. This was done through the identification of the strategies and schemes that the users employ, in addition to the domain related entities. As a result design requirements of the ALD were generated; these were thoroughly discussed in Chapter 9. These requirements were translated into a visual form where these entities were used to reflect the externalization's low-level visual cues; whereas the strategies were used as a guide for the

design of the externalization's layout and associated interface related interactions. Details of this were discussed in Chapter 6.

10.3The InfoVis Instrument Design

The design of the InfoVis instrument addresses three of the contributions of this research; these are:

- Requirements translation into an InfoVis design
- Experiential design implications
- Personalization of InfoVis tools

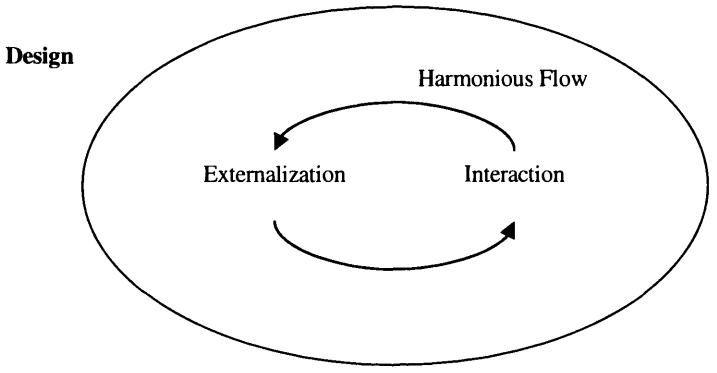


Figure 10.2 The design of an InfoVis instrument: A continuous flow of Interaction between manipulation and externalization

Figure 10.2, an expansion of the design step presented in Figure 10.1, divides the design process into two interrelated steps, the externalization design and the interaction design. Both need to be taken into account when designing InfoVis instruments.

10.3.1 Designing the externaiization of the domain

The externalization of the domain is a crucial component of the design process as it represents what the user will use as the basis of the interaction, as discussed in Chapter 9. In this part of the design, the layout of the visual representation and the visual encodings are decided upon. The visual encoding is used to represent the domain related entities, such as colour, shape, etc. The externalization design was divided into two steps:

- Assigning visual cues to the low-level domain related entities: author, number of publications, publication, etc.
- Determining the layout of the externalization which is dependent on the schemes that users use in order to make sense of the domain.

Chapter 6 gives a detailed account of the manner in which the externalization was designed based on the findings of the requirements study.

10.3.2 Designing the manipuiative operations

When it comes to designing the manipulative operations of InfoVis instruments, these are looked at from the semantics of their associated feedback: *formal* and *informal* (Chapter 9). Formal operators reflect the manipulative activities that users engage with in order to manipulate the externalization, such as zoom, filter, pan, etc. Within the context of InfoVis these can be looked at from the perspective of Shneiderman's (1996) information seeking mantra: overview, zoom and filter, details on demand. On the other hand, informal operators are necessary as they allow for greater personalization of the tool which was observed as being crucial for delivering a subjective experience.

The difference between formal and informal operators, as discussed in Chapter 9, lies on the fact that informal operators are operators that do not rely on computational algorithms. Rather, they are imposed by individual users to assist them in their sensemaking efforts. Users appropriate them for their own needs. The semantics of these operators cannot be predetermined by the designer as their use differs from one user to the other. InfoVis tools currently are not being designed for the users. This research argues that in order to design for the user that users' subjective conceptualizations should be taken into account, especially when it comes to designing visualization for a domain such as the academic literature domain which has a highly social and conceptual nature. In order to do so, such conceptualization should be reflected as part of the externalization's design.

10.3.3 Seamlessness: Harmonious flow of interaction

Both the externalization and the manipulative operations need to be designed in a manner that will allow for a harmonious flow of interaction. This research has pointed to the fact that pragmatic manipulative activities should not interfere with the epistemic sensemaking activities when it comes to users' interactive experiences (Chapter 8). In order to do so, this research suggests looking at the pragmatic manipulative activities in terms of primary and secondary activities. Where the primary activities are the manipulative activities that users engage with while making sense of the domain such as, revealing a relationship, looking at the details of an entity, etc. These activities are the activities that are related to the manipulation of an individual entity. The secondary activities are the supportive activities such as, filter, zoom, search etc. By looking at these activities from the

perspective of instrumental interaction (Beaudouin-Lafon, 2000), it is argued that all secondary and primary activities should have a degree of integration that is close to 1, that is, the physical actions that users are taking needs to be compatible with their responsive effects on the object. When it comes to the primary activities all should have a small spatial and temporal offset. The distinction between the primary and secondary activities is difficult; however, it can be refined as part of the iterative design-evaluation process.

It is important to note that interaction design is an iterative process that takes into account designing a harmonious flow of interaction between the externalization and manipulation operators. Hence, these design steps cannot be looked at separately. Another way to tackle the instrumental design process would be to involve users in the design process of the tool, a participatory style of design. Through participatory design, users influence not only the requirements, but also the layout of the externalization, e.g. (Craft & Cairns, 2006).

10.4 Evaluating the Instrument

Contributions to the InfoVis field were addressed as part of the evaluation process; these are listed as follows:

- An experiential stance on evaluating InfoVis tools
- Unpacking the meaning of interaction within the context of InfoVis
- Identifying the limitations of usability for evaluating InfoVis tools

When evaluating an InfoVis tool, users' experiences needs to be taken into account. This involves both the pragmatic activities and the epistemic activities. Pragmatic activities result from users' interaction with the tool and epistemic activities result from users' subjective sensemaking experiences. Hence, the evaluation process is divided into two steps: evaluating the tool and evaluating the subjectivity of the experience. Evaluating the tool reflects the evaluation of the interface, and evaluating the subjectivity of the experience determines whether or not the users are able to appropriate the tool into an instrument.

10.4.1 Evaluating the tool

The tool is an important part of users' overall experiences as it represents the mechanics with which the user interacts in order to gain insight and knowledge of the represented domain. The InfoVis tool is made out of the externalization embedded within an interface. Therefore the tool's usability needs to be addressed from two perspectives, effectiveness and efficiency. Effectiveness deals with

the usability of the externalization and its associated visual cues and efficiency relates to the manipulative activity.

Effectiveness: Evaluating the externaiization

The externalization of the tool reflects the visual encodings that are used to communicate domain related information to the user. As a result, its evaluation is crucial. In order to evaluate the externalization of the tool, the tasks that were given to the users were based on visual taxonomies, as explained in detail in Chapter 7. These tasks mostly represented low-level tasks that were based on the requirement gathering study (Chapter 5). As users executed these tasks, the effectiveness of the visual cues in communicating the intended meaning was captured. As seen in Chapter 7, in task-based evaluation studies users are mainly focused on executing the pre-devised tasks so they do not fully explore the knowledge that the tool offers in a natural manner, hence the correctness of their answers does not really reflect the ability of the users in gaining deep understanding of the domain. As a result, it is suggested that the effectiveness of the tool should be based on whether the users are able to understand the encodings used and not whether they are able to gain insight.

Efficiency: Evaluating the interaction mechanics

When it came to evaluating the efficiency of the tool, the time it took users to accomplish the tasks was an inappropriate measure. This was discussed in detail in Chapter 7. However, it was identified that the efficiency measures need to reflect the mechanics of the interaction, which are indicated by the manipulative activities that the users engaged with and whether or not they allow for seamlessness of the interaction. An effective measure of effectiveness was suggested as being the number of physical activities that users would engage with in order to execute a task, but this needs to be further investigated.

Evaluating the tool is an essential part of evaluating the overall users' InfoVis experiences. Relying on task-based usability studies assists in such a process leading to a re-design. This study also assisted in better understanding the measures needed for capturing the usability of the InfoVis interfaces. However, this study, like many InfoVis evaluation studies, concentrated on the tool part of the experience ignoring the subjectivity aspect. In other words, the studies are devised to evaluate users' pragmatic operations without taking into account the epistemic activities. The epistemic activities, as discussed, are the primary activities involved in users' InfoVis experiences. Hence, they should be taken into account; this is discussed next.

10.4.2 Evaluating subjectivity of the experience

The experiential study conducted in Chapter 8 aimed at generating a theoretical understating of users' interaction with the InfoVis tool. The generated theory (Chapter 8) has shown that the process of appropriating the tool into an instrument is the essence of users' InfoVis experiences. Appropriation is subjective, as it depends on users' internalizations of the world. This leads to emphasizing the importance of evaluating the subjectivity of the InfoVis tool. Currently available quantitative measures such as existing questionnaires are not able to capture such subjectivity. In order to do so, a longitudinal case study would be ideal in such a situation. However, these types of studies are not always possible. As a result, an exploratory lab-based study was conducted.

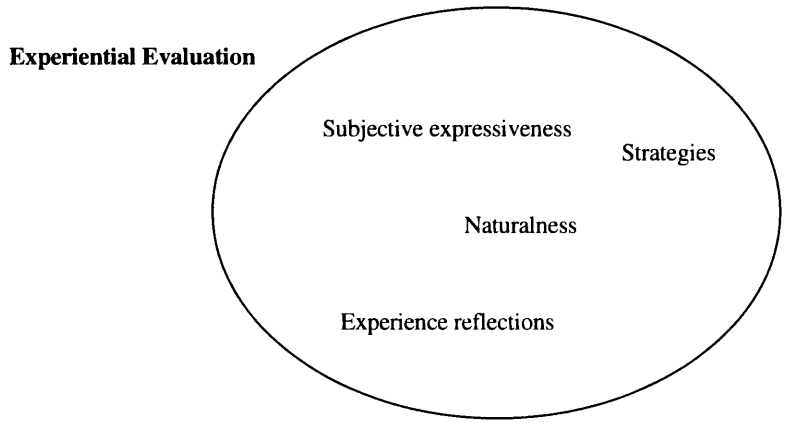


Figure 10.3 Pointers on what to look for when evaluating the subjectivity of the InfoVis experience

The study was conducted in a manner that allowed users to interact freely with the tool in order to accomplish a realistic high-level task. Grounded Theory (GT) was used to analyse the collected data. This is not the first attempt of using GT to study users' interaction with InfoVis tools, there are a few other attempts such as: Mark, Carpenter, & Kobsa (2003) used GT in order to build a model of the process with which people solve problems using InfoVis in a collaborative setting, and Tory & Staub-French (2008) used GT to extend their understanding of the generated quantitative results which attempts to understand the complex processes involved in collaborative design meetings. Both of the mentioned studies base the analysis on video data. In addition they both look at users' interaction in collaborative settings which, differs from the focus of this study, but neither attempts to generate theory. In addition, the model built by Mark et al (2003) does not explicitly look at users activities when interacting with the InfoVis tool from the perspective of both the interface and the sensemaking processes as this research does. From my experiences in understanding users' interaction with the ALD InfoVis tool the following pointers are summarised as the main categories of observational and interview data from which the theory was built (Figure 10.4):

1. Personal strategy – identify the strategy that the users are using in order to make sense of the externalization
2. Naturalness – determine whether this strategy fits within the context of the design rationale
3. Experience reflection – determine how the users reflect upon their experiences and whether this reflection is related to the tool or the instrument
4. Expressiveness of subjectivity – determine whether the tool assisted the user in expressing the subjectivity of their experiences as part of the interaction process

The output of the evaluation process might result in suggestions for re-design of the tool and the process will go on, as presented in Figure 10.1. This figure represents the design and evaluation framework of InfoVis instruments. As can be seen in the figure, this process is very iterative, leading to a redesign following every stage. It is only through users' interaction with the tool that further understanding of users' additional appropriation needs is gained which leads to further enhancements to the tool's design. The aim of designing an InfoVis instrument is to allow for the tool to be effectively transformed into an instrument by the user. A designed instrument can only be delivered following the users' subjective interaction. Currently applied design and evaluation strategies deliver tools and not instruments, leading to designs that cannot be effectively appropriated by users. Hopefully, by designing InfoVis tools that can be effectively appropriated into instruments, better InfoVis tools will reach the user.

This research has resulted in the creation of an InfoVis interaction model (Figure 10.5). This model can be evaluated along the three dimensions that Beaudouin-Lafon (2004) describes (p. 17):

- Descriptive power – the ability to describe a significant range of existing interfaces
- Evaluative power – the ability to help access multiple design alternatives
- Generative power – the ability to help designers create new designs

The generated InfoVis experiential model (Chapter 8) strikes a balance along these dimensions. It has good descriptive power due to its generalisability as it is based on the generation of theory which can be applicable to other InfoVis tools, it has good evaluation power as it allowed for the evaluation of the ALD InfoVis tool as described in this chapter, and last but not least it has good generative power due to ability to generate new design ideas as described in detail in Chapter 9.

10.5 Limitations and Future Work

The approach that this research has taken in order to address the main research question was a prototype centred one, where a prototype was developed and formed the centre of all the user studies. Another approach could have been taken which was to conduct a comparative study between the developed prototype and an existing prototype and look at the users' experiences from that perspective. However, that could not have been done due to the fact that no tool was found that fitted the needs of this research as explained in Chapter 4. Having to develop two tools would have been an impossible task due to the time constraints and the manpower involved. The results of this research are centred on a prototype, yet they are generalisable in light of the mirroring of the instrumental genesis approach. Looking at InfoVis as an experience, an instrument, rather than a tool is a first in the field of InfoVis which opens the door for many more research questions and opportunities. These will be discussed in light of the InfoVis experiential model discussed in Chapter 8, and presented again in Figure 10.5 to facilitate the discussion.

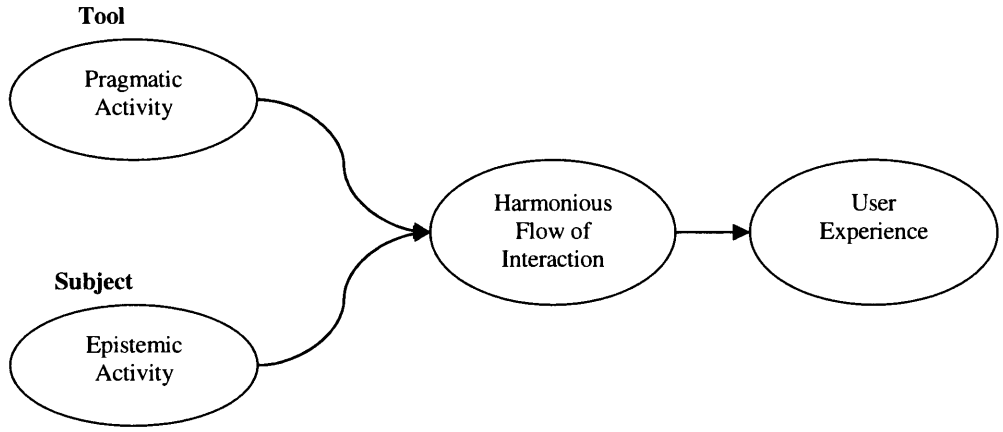


Figure 10.4 The InfoVis experiential model

10.5.1 The tool

When it comes to the tool and the ways in which it affects the experience, the question that can be asked is: how does the tool affect the overall experience? In this case improvement on the tool, as suggested in Chapter 9, could be conducted and from there determine the effects that such would have on users' experiences, such as the integration of the tool with other academic literature tools. This will give further insight into users' InfoVis experiences which would allow for the expansion and strengthening of the theory (Figure 10.5).

In addition, the theory has shown that when it comes to the tool, there needs to be a harmony of interaction between the visual activities and the physical activities. Hence, the question that can be asked is the following: is this harmony the only relationship that needs to be addressed? This question can be addressed by manipulating its variables. One suggestion can be to use additional input devices such as a 3D mouse or a joystick for navigating the space instead of the mouse and studying how this will affect users' experiences through a comparative study that will compare both interfaces. The goal is to identify whether this would have an effect of users' overall experiences and whether there is another relationship that is being identified between the visual and the physical activities. Such a finding will add strength to the theory.

10.5.2 The subject

In addition to the tool, the other component that is crucial to users' InfoVis experience is the subjectivity of the experience. The subjectivity of the experience is dependent on users' backgrounds and past experiences of interacting with the domain. This in turn will have an effect on the strategies that users' will adopt and the schemes that they will employ in order to make sense of the externalization. Externalizations are the products of computational algorithms that are based on designers' conceptualization of the domain. As a result, the external layout and associated functionalities may not fit all users' sensemaking schemes. Hence, further research needs to be conducted in order to explore the idea of personalization by investigating the effects that such will have on users' overall experiences. A suggestion could be to overlay the externalization with an interface that would allow for full customizability by the users. When users interact with this interface they would be able, not merely to change the color of the nodes, as with the 'marking tool' (Chapter 6), but also to do things like:

- Hide nodes and edges
- Add comments to links and nodes (post-it style)
- Extract parts of the externalization
- Customize the layout
- etc

As a result, it would be interesting to see the effects that that would have on users' InfoVis experiences and the means with which users make sense of the externalization, and whether or not such personalization would allow users to overcome the negativity of the experience. In addition, allowing for greater appropriation may lead to the identification of additional functionalities needed as part of the InfoVis interface that were not previously identified.

10.5.3 The experience

In addition to the identified components of experience, further research needs to be conducted in order to investigate the concept of interaction within the context of InfoVis. For example, longitudinal case studies and diary studies would reveal interesting information that can be added to the base experiential model suggested by this research. In addition, due to the lack of an InfoVis evaluation framework or methodology, devising one based on the theoretical grounding of users' InfoVis experiences would be of great benefit to the community. Last but not least, the generated experiential InfoVis theory was based on users' interaction with the ALD InfoVis prototype. Further validations needs to be conducted in order to identify the applicability of the theory when it comes to users' interaction with other subjective application domains.

10.5.4 Summary

To conclude, this research has presented a holistic view on users' InfoVis experiences by pointing to the categories and concepts that are crucial for users' InfoVis experiences. In doing so, a visualization of the ALD was developed. It is the development and evaluation process that led to the generation of this research's contributions. The generation of theory and not merely reliance on prototype centred findings is crucial if we want to design good InfoVis tools. This is due to its generalisability and expandability, meaning that as researchers we will be able to build on each others' work until a theory of InfoVis interaction is generated. I hope that the findings of this research will change the ways in which InfoVis researchers look at InfoVis tools in terms of seeing them as more than just tools but as experiences, as instruments.

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Appendix A: Requirements Study

General Information Sheet

"Learning About Your Research Area"

Thank you for volunteering to participate in this study. The aim of this study is to gain a general understanding of how people learn about their research area. This study will be shaped in the form of a semi-structured interview in which you will be asked questions relating to your own experiences as a researcher. The recording of this interview depends entirely on your consent. If you would agree to the recording, you may be confident that the recorded information will be strictly used for the purpose of this study only.

The whole interview takes about 45 minutes. If a question during the interview is not clear to you please feel free to indicate that. While the researcher will be happy to answer any general questions you may have, s/he has been instructed not to discuss some aspects of the study until the end. Please be assured that your identity will be kept strictly confidential and any report of the study will not identify you personally.

You will be given a Consent Form pertaining to this study very shortly. Please read and sign the form.

Consent Form

Title of Study: "Learning About Your Research Area"

1. I confirm that I have read and understood the information sheet dated..... for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.

3. I agree to take part in the above study.

4. I .....the recording of this interview. (accept/decline)

Participant name	Date	Signature
Researcher	Date	Signature

Initial stage sample list of questions

General background questions
Work, research interests, experience in doing research.

Literature
Questions regarding the literature experience were formed around the following:

1. Situations in which the researcher works with literature
2. The means in which the researchers works with literature
3. The processes involved in finding literature of interest
4. The criteria for determining the relevance of a paper
5. Type of knowledge that is gained from literature
6. The ways in which literature is organized
7. The value of literature to the individual
8. Whether or not there was a specific paper or author that were important to the researcher and the reasons for that and would that make them influential
9. Whether or not the researcher feels part of a community

Intermediate stage sample list of questions

General background questions
Work, research interests, experience in doing research.

Research Community
Researchers were asked to clarify:

1. What was meant by research community
2. Whether being part of a community was important
3. The reasons for that.

Literature
Questions regarding the literature experience were formed around the following:

1. Situations in which the researcher works with literature
2. The means in which the researchers works with literature
3. The processes involved in finding literature of interest
4. The criteria for determining the relevance of a paper
5. Type of knowledge that is gained from literature
6. The ways in which literature is organized
7. The importance of literature to the individual

Literature experiences
Researchers were asked to explain the ways in which they worked with literature and how that has changed overtime

Influence/Dominance
Researchers were asked to:

1. Clarify the meaning of influence
2. Give examples of influential authors and publications
3. Describe the relationship between authors and publications

Higher level conceptualizations
Researcher were asked to elaborate on the higher level conceptualizations or knowledge that they generated as part of interacting with literature this led to the concept of the evolution of the discipline and hence it was further investigated.

Final stage sample list of questions

General background questions
Work, research interests, experience in doing research.

Research Community
Researchers were asked to clarify:

1. What was meant by research community
2. Whether being part of a community was important
3. The reasons for that.

Literature
Questions regarding the literature experience were formed around the following:

1. Situations in which the researcher works with literature
2. The means in which the researchers works with literature
3. The processes involved in finding literature of interest
4. The criteria for determining the relevance of a paper
5. Type of knowledge that is gained from literature
6. The ways in which literature is organized
7. The importance of literature to the individual

Literature experiences
Researchers were asked to explain the ways in which they worked with literature and how that has changed overtime

Influence/Dominance
Researchers were asked to:

1. Clarify the meaning of influence
2. Give examples of influential authors and publications

Author article relation
Researchers were asked to elaborate on the ways that they conceptualize about literature in terms of articles vs. authors

Evolution of a discipline
Researcher were asked to elaborate on the concept of the evolution of a discipline

Appendix B: Usability Study

General Information Sheet

"Evaluating the usability of an academic literature visualization tool"

Ethical Approval Code: PhD/2007/02

Thank you for volunteering to participate in this study. The goal of this study is to evaluate the usability of an information visualization tool. The tool represents a global view of an academic literature domain. The dataset used represents literature data of eight years of the InfoVis conference starting from 1995.

This study will take the form of a task-based evaluation study where you will be given a set of questions regarding the represented data, and be asked to answer them based on the domain information provided by the tool. It is important that you take your time, and answer each question correctly. During the course of this study the researcher will be taking notes in addition to measuring the time you need to answer each question. Hence, please answer the questions in sequence. Please do not be pressured by such an action. It is the system that is being measured not you. Prior to beginning the study you will be given a questionnaire. You will be asked to answer the first part of the questionnaire prior to beginning the study. The first part of the questionnaire aims at capturing your experience with Information Visualization tools in general and academic literature visualizations in specific. After conducting the study you will be asked to answer the second part of the questionnaire which aims at capturing your experiences whilst interacting with the tool. Prior to beginning the study you will be given fifteen minute training with the system where the researcher will explain the system in detail, and you will be given the opportunity to interact with the system.

The whole study takes approximately 75 minutes. If one of the task related questions during the study is not clear please feel free to indicate that. While the researcher will be happy to answer any general questions you may have, she is not able to discuss some aspects of the study until the end. Please be assured that your identity will be kept strictly confidential and any report of the study will not identify you personally. If at any time during the study you feel that you want to withdraw for ant reason please feel free to do so. Please note that the tool visualizes a single dataset and hence the information provides does not in any way reflect the research career of any of the researchers visualized by the tool.

You will be given a Consent Form pertaining to this study. Please read and sign the form.

Thank you.

Consent Form

Title of Study: "Evaluating the usability of an academic literature visualization tool"

1. I confirm that I have read and understood the information sheet dated..... for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.

3. I agree to take part in the above study.

4. I ..... that my actions be observed by the researcher. (accept/decline)

Participant name	Date	Signature
Researcher	Date	Signature

Background and QUIS

Identification number: _____

System code: _____

Age: _____

Gender: ____ **male**

____ **female**

Please answer the following questions, if at anytime you do not wish to answer certain questions please feel free to do so.

PART 1: Researcher Background Information

1.1 How long have you worked with computers?

__ less than 2 years
__ 2 to 5 years
__ 5 to 10 years
__ 10 years or more

1.2 How long have you been doing research for?

__ 1 year or less
__ 2-3 years
__ 3-5 years
__ 5-10 year
__ more than 10 years

1.3 What is your current academic status?

_____

PART 2: System Experience

2.1 Do you know what an Information Visualization tool is?

__ Yes
__ No

If your answer is yes, please give a brief explanation of your understanding:

_____
_____
_____
_____

2. 2 Have you ever worked with an Information Visualization Tool?

__ Yes
__ No

If your answer is yes, please give examples and indicate the reasons for using these tools.

_____

2. 3 Are you familiar with Information Visualization literature?

__ Not familiar
__ Familiar
__ Average knowledge
__ Expert

2. 4 Are you familiar with InfoVis 2004 dataset?

__ Yes
__ No

If your answer is yes, please the reasons of this familiarity:

PART 3: Academic Literature Experiences

On the average, how much time do you spend per week working with literature?

__ less than one hour
__ one to less than 4 hours
__ 4 to less than 10 hours
__ over 10 hours

Please write your comments about you average use of academic literature:

When working with academic literature, what computer tools do you use for searching and organizing your literature?
Please list the tool and the reasons for using each one:

3.2 Do you use any tools for generating overviews of your literature?

__ Yes
__ No

If your answer is yes, please indicate the tools:

Have you used any Information Visualization tools for working with academic literature?

__ Yes __ No

If your answer is yes, please give examples and indicate the reasons for using these tools.

_____
_____
_____
_____

Next Sections are to be completed after the completion of the study.

PART 4: Overall User Reactions

Please circle the numbers which most appropriately reflect your impressions about using this computer system.
Not Applicable = NA.

4.1	Overall reactions to the system:	terrible 1 2 3 4 5 6 7 8 9	wonderful	NA
4.2		frustrating 1 2 3 4 5 6 7 8 9	satisfying	NA
4.3		dull 1 2 3 4 5 6 7 8 9	stimulating	NA
4.4		difficult 1 2 3 4 5 6 7 8 9	easy	NA
4.5		rigid 1 2 3 4 5 6 7 8 9	flexible	NA

Screen

5.1	Characters on the computer screen	hard to read 1 2 3 4 5 6 7 8 9	easy to read	NA
5.2	Screen layouts were helpful	never 1 2 3 4 5 6 7 8 9	always	NA
5.2.1	Amount of information that can be displayed on screen	inadequate 1 2 3 4 5 6 7 8 9	adequate	NA
5.2.2	Arrangement of information on screen	illogical 1 2 3 4 5 6 7 8 9	logical	NA
5.3	Multiple views on the screen	confusing 1 2 3 4 5 6 7 8 9	clear	NA
5.3.1	Relating information	impossible 1 2 3 4 5 6 7 8 9	easy	NA
5.3.2	Progression of work related tasks	confusing 1 2 3 4 5 6 7 8 9	clearly marked	NA

Please write your comments about the screen here:

Learning

6.1	Learning to operate the system	difficult 1 2 3 4 5 6 7 8 9	easy	NA
6.1.1	Getting started	difficult 1 2 3 4 5 6 7 8 9	easy	NA
6.1.2	Time to learn to use the system	slow 1 2 3 4 5 6 7 8 9	fast	NA
6.2	Exploration of features by trial and error	discouraging 1 2 3 4 5 6 7 8 9	encouraging	NA
6.2.1	Exploration of features	risky 1 2 3 4 5 6 7 8 9	safe	NA
6.2.2	Discovering new features	difficult 1 2 3 4 5 6 7 8 9	easy	NA
6.3	Remembering use of commands	difficult 1 2 3 4 5 6 7 8 9	easy	NA
6.4	Tasks can be performed in a straight-forward manner	never 1 2 3 4 5 6 7 8 9	always	NA
6.4.1	Number of steps per task	too many 1 2 3 4 5 6 7 8 9	just right	NA
6.4.2	Steps to complete a task follow a logical sequence	never 1 2 3 4 5 6 7 8 9	always	NA
6.4.3	Feedback on the completion of	unclear 1 2 3 4 5 6 7 8 9	clear	NA

Please write your comments about learning here:

System Capabilities

7. 1	System speed	too slow 1 2 3 4 5 6 7 8 9	fast enough	NA
	7.1.1 Response time for most operations	too slow 1 2 3 4 5 6 7 8 9	fast enough	NA
	7.1.2 Rate information is displayed	too slow 1 2 3 4 5 6 7 8 9	fast enough	NA
7. 2	The system is reliable	never 1 2 3 4 5 6 7 8 9	always	NA
	7.2.1 Operations are	undependable 1 2 3 4 5 6 7 8 9	dependable	NA
	7.2.2 System failures occur	frequently 1 2 3 4 5 6 7 8 9	seldom	NA
7. 3	Correcting your mistakes	difficult 1 2 3 4 5 6 7 8 9	easy	NA
	7.3.1 Correcting typos	complex 1 2 3 4 5 6 7 8 9	simple	NA
	7.3.2 Ability to undo operations	inadequate 1 2 3 4 5 6 7 8 9	adequate	NA
7. 5	Ease of operation depends on your level of experience	never 1 2 3 4 5 6 7 8 9	always	NA
	7.5.1 You can accomplish tasks knowing only a few commands	with difficulty 1 2 3 4 5 6 7 8 9	easily	NA

Please write your comments about system capabilities here:

Colors

8.1	Colors used are	unclear 1 2 3 4 5 6 7 8 9	clear	NA
8.1.1	Meaning of the various colors	confusing 1 2 3 4 5 6 7 8 9	understandable	NA

Please write your comments about colors here:

_____

_____

_____

_____

Part 5: General Comments

5.1 How well do you think you did on the tasks?

poorly excellently
1 2 3 4 5 6 7 8 9

5.2 Which tasks were the most difficult and Why?

_____

_____

_____

5.3 Would you use such a system to explore a literature domain?

__ Yes __ No

Comments:

_____

_____

_____

5.4 Do you have any general comments or comments for improving the system?

_____

_____

_____

System Training Tasks

Title: "Evaluation the Usability of an academic literature visualization tool"

Using the Literature Knowledge Visualization tool, answer the following question:

1. Search for *Woodruff*?

2. What are the types of her publications?

_____

_____

3. Select her 1996 publication, who collaborated wit her on that publication?

_____

_____

4. How many papers cited her 1997 paper? How many of those were written by her? How many papers cited these papers?

_____

_____

5. Collapse the citation tree.

6. Insert *Woodruff* into the author citation view.

7. Of the authors that collaborated with her on her 1997 paper, how many of them does she cite?

_____

_____

8. Of the authors that she cites, who is the author with the highest number of publications?

_____

_____

9. Which one of *Woodruff's* papers cites *Shneiderman*? How many times is he cited? What are the titles of *Shneiderman's* papers?

10. Who collaborated with *Ivan Herman*?

Task Sheet

Identification number: _____
System Code: _____

Title: "Evaluation the Usability of an academic literature visualization tool"

Using the Literature Knowledge Visualization tool, answer the following question:

11. Which research interest is associated with more authors?

_____

_____

12. If Shneiderman had a new publication written in 2002 and was cited 25 times where would it be located on the screen?

_____

_____

13. Of the papers that have been published by *Shneiderman* which has been cited the most?

_____

_____

14. Locate *Shneiderman's* 2001 paper, what are its keywords?

_____

_____

15. Rank *Shneiderman* and *Pirolli* according to the highest status paper. (Status = number of citations)

_____

_____

16. Categorize *Hans-Peter Kriegel's* publications according to the type of publications (type = Journal, workshop, ...)

_____

17. *Jim Thomas's* publications are associated with which conference?

18. Who are the authors that collaborate with *Chris Hand*?

19. How many papers written by *Bederson* does his 1999 paper cite?

20. Who co-authored with *Qing-Wen Feng* on his 1996 "Multilevel Visualization of Clustered Graphs" paper?

21. Of the authors that collaborated with *John Riedl* who has published the most?

22. *Tamara Munzner* cites a few authors including *Paul Burchard*. Who does *Paul Burchard* cite?

23. The 1996 "Eyes have it ..." paper by *Shneiderman* cites another paper by *J. A. Wise*, the latter paper cites another paper, who are the co-authors of that paper?

24. *Loannis G. Tollis* cites *Janet M. Six* how many papers did they co-author?

25. *Benjamin B. Bederson's* 1995 higher status paper is cited by one of his collaborators, identify which one? (status = number of times paper was cited)

26. *Nina Amenta* and *Jeff Klinger*are collaborators, have any of them collaborated with other authors?

27. Of the authors that cited *Peter Krogh*, three of them collaborated with him. Can you identify which ones?

28. What is the relationship between the following authors: *Jim Thomas, Paul Whitney*?

29. One of *Ivan Herman's* 2000 papers is cited by one of *Jarke J. Van Wijk's* papers can you identify the title of *Wijk's* paper?

30. All the authors that cite *Peter Krogh* collaborate on one of *Michael Christensen's* papers, identify its type and research interest.

31. *Lucy Nowell's* 2002 journal paper is associated with *Ulrika Brandes's* and *Steven R. Corman*, identify the grounds of this relation.

32. In what way are *Peter Eades* and *Stephan G. Eick* related?

Users' Responses to the Questionnaire on a scale of 1 - 9

Overall Reaction

	U1	U2	U3	U4	U5	U6	U7	Median
Overall reactions to the system (terrible - wonderful)	5	6	7	5	7	5	6	6
(frustrating - satisfying)	4	5	6	4	6	5	6	5
(dull - stimulating)	7	8	7	7	7	7	6	7
(difficult - easy)	4	5	5	3	5	4	3	4
(rigid - flexible)	7	4	9	5	6	6	5	6

Screen

	U1	U2	U3	U4	U5	U6	U7	Median
Characters on the computer screen (hard to read - easy to read)	4	8	6	7	4	4	4	5
Screen layouts were helpful (never - always)	6	6	6	7	6	5	5	6
Amount of information that can be displayed on screen (in adequate - adequate)	8	7	9	4	5	3	6	6
Arrangement of information on screen (illogical - logical)	7	8	7	6	7	3	6	6
Multiple views on the screen (confusing - clear)	6	6	1	7	7	4	5	5
Relating information (impossible - easy)	6	7	5	7	6	4	4	6
Progression of work related tasks (confusing - clearly marked)	6	7	5	6	6	6	5	6

Learning

	U1	U2	U3	U4	U5	U6	U7	Median
Learning to operate the system (difficult - easy)	6	8	3	2	7	6	3	5
Getting started (difficult - easy)	6	6	6	7	6	4	4	6
Time to learn to use the system (slow - fast)	6	6	5	4	6	5	3	5
Exploration of features by trial and error (discouraging - encouraging)	6	6	7	8	8	8	3	7
Exploration of features (risky - safe)	6	8	5	9	7	8	6	7
Discovering new features (difficult - easy)	6	7	5	8	5	8	6	6
Remembering use of commands (difficult -easy)	6	7	7	3	6	8	3	6
Tasks can be performed in a straight-forward (never - always)	3	8	7	6	6	6	5	6
Number of steps per task (too many - just right)	6	6	8	8	5	4	5	6
Steps to complete a task follow a logical sequence (never - always)	6	8	8	7	5	6	5	6
Feedback on the completion of sequence steps (unclear - clear)	6	6	6	9	5	9		7

System Capabilities

	U1	U2	U3	U4	U5	U6	U7	Median
System speed (too slow - fast enough)	6	8	9	2	8	7	4	6
Response time for most operations (too slow - fast enough)	3	8	9	5	8	4	5	6
Rate information is displayed (too slow - fast enough)	7	8	9	3	8	4	5	6
The system is reliable (never - always)	4	9	8	4	5	5	4	6
Operations are (undependable - dependable)	5	9	8	9	8	7	6	7
System failures occur (frequently - seldom)	8	8	9	4	5	6	4	6
Correcting your mistakes (difficult - easy)	7	7	9	8	6	3	6	7
Correcting typos (complex - simple)	9	9	9	9	8	4	8	8
Ability to undo operations (inadequate - adequate)	8	7	9	8	8	1	6	7
Ease of operation depends on your level of experience (never - always)	6	8	3	3	5	7	8	6
You can accomplish tasks knowing few commands (with difficulty - easily)	7	7	9	8	4	6	7	7

Color

	U11	U12	U13	U14	U15	U16	U17	Median
Colors used are (unclear - clear)	7	8	5	9	6	4	5	6
Meaning of the various colors (confusing - understandable)	9	7	3	9	8	3	6	6

Appendix C: Experiential Study

General Information

"Capturing the InfoVis Experience"

Ethical Approval Code: PhD/2007/03

Thank you for volunteering to participate in this study. The goal of this study is to capture the experience of users' interaction with an Information Visualization (InfoVis) tool. The tool represents a global view of the InfoVis literature domain. The dataset used represents literature data of eight years of the InfoVis conference starting from 1995.

Given a scenario, you will be asked to identify a set of action that you would normally do in order to discover information about a particular concept or idea. The system will then be explained and you will be given fifteen minutes training with the system through a set of tasks that you will perform with the researcher. Then you will be asked to freely interact with the tool to gain insight and knowledge of a particular concept. During the course of this study the researcher will be taking notes. In addition, audio and video recordings of your interaction with the tool will be captured. Prior to beginning the study your demographic information will be gathered and your background experience with Information Visualization tools in general and academic literature visualizations in specific will be captured. After conducting the study you will be interviewed by the researcher and asked to reflect back on your experiences interacting with the tool. The interview will be recorded.

The whole study takes approximately 75 minutes. If you need to ask the researcher questions about specific functionalities of the tool during the study please feel free to do so. While the researcher will be happy to answer any general questions you may have, she is not able to discuss some aspects of the study until the end. Please be assured that your identity will be kept strictly confidential and any report of the study will not identify you personally. If at any time during the study you feel that you want to withdraw for any reason please feel free to do so.

Please note that the tool visualizes a single dataset and hence the information provided does not, in any way, reflect the research career of any of the researchers visualized by the tool.

You will be given a Consent Form pertaining to this study. Please read and sign the form.

Thank you.

Consent Form

Title of Study: "Capturing the InfoVis Experience"

5. I confirm that I have read and understood the information sheet dated..... for the above study and have had the opportunity to ask questions.

6. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.

7. I agree to take part in the above study.

8. I ..... that my actions be observed by the researcher. (accept/decline)

9. I ..... that the interview be recorded by the researcher. (accept/decline)

Participant name	Date	Signature

Researcher	Date	Signature

Background Information Sheet

Identification number: _____

System code: _____

Age: _____

Gender: ____ **male**

____ **female**

PART 1: Researcher Background Information

1.1 How long have you worked with computers?

__ less than 2 years

__ 2 to 5 years

__ 5 to 10 years

__ 10 years or more

1.2 How long have you been doing research for?

__ 1 year or less

__ 2-3 years

__ 3-5 years

__ 5-10 year

__ more than 10 years

1.3 What is your current academic status and field?

_____

PART 2: System Experience

2.1 Do you know what an Information Visualization tool is?

__ Yes

__ No

If your answer is yes, please give a brief explanation of your understanding:

_____

_____

_____

_____

2.2 Have you ever worked with an Information Visualization Tool?

__ Yes __ No

If your answer is yes, please give examples and indicate the reasons for using these tools.

_____

_____

_____

_____

1.3 Are you familiar with Information Visualization literature?

__ Not familiar __ Average knowledge

__ Familiar __ Expert

2. 4 Are you familiar with InfoVis 2004 dataset?

__ Yes __ No

If your answer is yes, please the reasons of this familiarity:

_____

_____

_____

_____

PART 3: Academic Literature Experiences

3.1 On the average, how much time do you spend per week working with literature?

__ less than one hour __ 4 to less than 10 hours

__ one to less than 4 hours __ over 10 hours

Please write your comments about you average use of academic literature:

_____

_____

_____

3.2 When working with academic literature, what computer tools do you use for searching and organizing your literature?

Please list the tool and the reasons for using each one:

3.2 Do you use any tools for generating overviews of your literature?

__ Yes __ No

If your answer is yes, please indicate the tools:

3.3 Have you used any Information Visualization tools for working with academic literature?

__ Yes __ No

If your answer is yes, please give examples and indicate the reasons for using these tools.

Training Task question and answer sheet

Identification number: _____
System Code: _____

Title: "Capturing the InfoVis Experience"

Using the Literature Knowledge Visualization tool, answer the following question:

33. Which research interest is associated with the least authors?

_____

_____

34. Who are the authors that collaborate with *Shneiderman*?

_____

_____

35. Of the papers that have been published by *Shneiderman* which has been cited the most?

_____

_____

36. Locate *Shneiderman's* 2001 paper, what are its keywords?

_____

_____

37. The 1996 "Eyes have it ..." paper by *Shneiderman* cites another paper by *J. A. Wise*, the latter paper cites another paper, who are the co-authors of that paper?

_____

_____

38. How many publications did *Loannis G. Tollis* and *Janet M. Six* co-author?

39. Of the authors that collaborated with *John Riedl* who has published the most?

40. *Benjamin B. Bederson's* 1995 publications are associated with which conference?

41. How many papers written by *Benjamin B. Bederson* does his 1999 paper cite?

42. One of *Ivan Herman's* 2000 papers is cited by one of *Jarke J. Van Wijk's* papers can you identify the title of *Wijk's* paper?

Task Sheet

Identification number: _____
System Code: _____

Title: "Capturing the InfoVis Experience"

Scenario: At this point of your research you need to examine the concept of "Dynamic Queries" you do not know where to start. A colleague of yours has given you a paper reference as a good starting point: a paper written by Shneiderman in 1996 and is titled "Incremental ..." Your goal is to identify key researchers and publications that target this area and identify any commonalities or differences between these groups of people.

Please use the literature visualization tool in order to tackle this problem and stop as soon as you feel that you have gathered enough insight. Please feel free to as the researcher at any point for assistance in relation to the functionality of the tool.

Use the following sheet/s to mark your answers in addition to any other notes you feel that you need to document as you are interacting with the tool.

Interview Questions

1. Can you please summarize what just happened?
2. Are there any incidents that you remember and why?
3. How did you feel while you were interacting with the tool?
4. What sort of experience would you say you had? (+ve –ve neutral) and Why?
5. What was you general impression of the tool
6. What were the main difficulties that you encountered
7. Please reflect back on your use of the tool and the insight gained.
8. Was the tool able to provide answers to the questions you generated?
9. Can you compare your use of the tool to other literature tools you use even paper and pencil